IRON AND STEEL ENGINEER

J. F. KELLY, Editor

CONTENTS

Volume II | September, 1925 | Number IX

IRON AND STEEL EXPOSITION—
- List of Exhibitors ... II
- Floor Plan ... III
- Letter of Welcome ... VI
- Executive Committee of Philadelphia Section ... VIII
- Map of Philadelphia ... XXII
- Exhibitors and what they will exhibit ... XXIII
- Official Program ... XXXV

Editorials ... VII

Direct Current Armature Windings for Multi-Polor Generators and Motors—Frogleg Windings—By W. H. Powell and G. M. Albrecht ... 345

How the Electrical Engineer and the Safety Engineer can be Mutually Helpful—By John A. Oartel ... 354

Report of Electric Heat Committee for 1925—By George H. Schaeffer, Chairman ... 356

Electric Heat Treating Furnace Applications—By E. A. Hurme ... 357

Electric Melting Furnaces—By J. A. Seede ... 368

Heating of Ingots by Electricity—By Ralph A. Butler ... 374

Auxiliaries and Auxiliary Drives for Steam Electric Generating Stations—By A. L. Penniman, Jr., and F. W. Quarles ... 377

The Selection and Maintenance of Oil Circuit Breakers—By George A. Burnham ... 384

Extending the Heat Cycle in Boiler Rooms by the Use of Preheated Air for Combustion Purposes—By J. G. Worker ... 391

Selection and Maintenance of Oil Circuit Breakers—By M. J. Wohlgemuth and E. K. Read ... 398

(List of Advertisers XXXVI)

Copyright, 1925, by Association of Iron and Steel Electrical Engineers.

Published Monthly by

Association of Iron and Steel Electrical Engineers

706 Empire Building, Pittsburgh, Pa.

Entered as second-class mail matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.

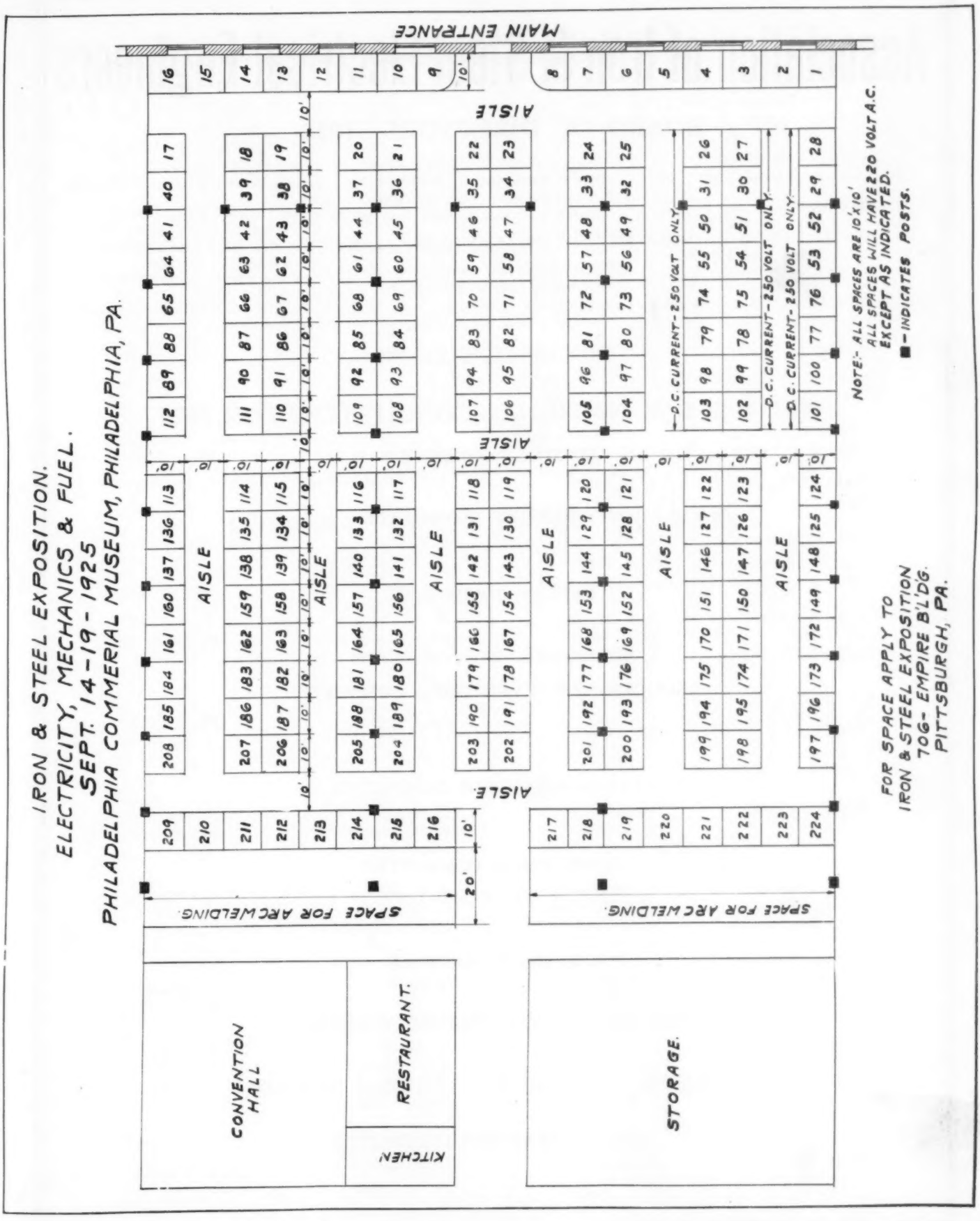
Subscription Price $5.00 per Year. Single Copy 50c.

LIST OF EXHIBITORS

AT

Iron and Steel Exposition

Name	Booth No.
Allen Bradley Co.	48
American Pressed Steel Co.	63
Allis Chalmers Mfg. Co.	83-94
Alliance Machine Co.	95
Appleton Electric Co.	195-198
American Electric Fusion Corp.	215
The Andresen Company	82
Baker R. & L. Co.	20-37
Bartlett Hayward Co.	27-30
Benjamin Elec. Mfg. Co.	39
Bussmann Mfg. Co.	107
Celite Products Co.	64
Cutler Hammer Mfg. Co.	26-31
Calebaugh Self Lub. Carbon Co.	41
The Cutter Electric & Mfg. Co.	77-100-101
Craven Electric Sales Co.	89
Crouse Hinds Co.	104-105
Chicago Fuse Mfg. Co.	130
Corliss Carbon Co.	131
Condit Elec. Mfg. Co.	178-179-166-167
Crocker Wheeler Co.	50
M. H. Detrick Co.	71
John C. Dolph Co.	222
Economy Electric Products Co.	213
Electric Development & Machine Co.	219
Edison Storage Battery Co.	35
Electric Storage Battery Co.	45
Erie Malleable Iron Co.	110
Electric Service Supplies Co.	113-136-137-160
Electric Controller & Mfg. Co.	114-135
Economy Fuse & Mfg. Co.	154
The Electric Journal	216
Fuels & Furnaces	208
Fuller Lehigh Co.	19 38
General Furnace Co.	129-144
General Electric Co.	145-152-153-168-169-176 177-192-193-200-201
Gehnrich Indirect Heat Oven Co.	223
Holophone Glass Co.	124
Hyatt Roller Bearing Co.	33
Heppenstall Forge & Knife Co.	210
Homestead Valve Mfg. Co.	220
The Hayward Co.	111
Johns Manville, Inc.	143
Keystone Lubricating Co.	120-121
Marlin Rockwell Co.	93
McGraw-Hill Co.	199
Morgan Engineering Co.	25-32
Monitor Controller Co.	47
Morganite Brush Co.	34
Martindale Elec. Co.	115
Mutual Elec. & Machine Co.	116
Mutual Foundry & Machine Co.	224
National Carbon Co.	108
National Elec. Mfg. Co.	109
Nichols Lintern Co.	206
Norma Hoffman Bearings Co.	17-40
New Departure Mfg. Co.	7
Ohio Elec. & Controller Co.	106
Otis Elevator Co.	132-141
Okonite Co.	51
Pittsburgh Transformer Co.	22-23
Packard Electric Co.	217-218
Pyle National Co.	112
Philadelphia Grease Mfg. Co.	194
Robinson Ventilating Co.	18
Rowan Controller Co.	24
Roller Smith Co.	43
Republic Flow Meters Co.	58
Rollway Bearings Co.	117
Reliance Elec. & Engrg. Co.	190-191-202-203
Shepard Elec. Crane & Hoist Co.	98
Square D. Company	8
Standard Underground Cable Co.	36
The Sharples Specialty Co.	76
SKF Industries, Inc.	102-103
Stackpole Carbon Co.	140
Schweitzer & Conrad	211
George Sachenmaier Co.	72
Trumbull Elec. & Mfg. Co.	21
Tinius Olsen Testing Machine Co.	60
Thomas Flexible Coupling Co.	88-65
Thompson Electric Co.	133
Tool Steel Gear & Pinion Co.	207
Harold E. Trent	173
United States Graphite Co.	122
V. V. Fittings Co.	118-119
Westinghouse Elec. & Mfg. Co.	156-157-164-165 188-189-204-205
E. L. Wiegand Co.	196-197


IRON & STEEL EXPOSITION.
ELECTRICITY, MECHANICS & FUEL.
SEPT. 14-19-1925
PHILADELPHIA COMMERIAL MUSEUM, PHILADELPHIA, PA.
MAIN ENTRANCE
AISLE
SPACE FOR ARC WELDING
CONVENTION HALL
RESTAURANT
KITCHEN
STORAGE
D.C. CURRENT-250 VOLT ONLY
NOTE:- ALL SPACES ARE 10'X10'
ALL SPACES WILL HAVE 220 VOLT A.C.
EXCEPT AS INDICATED.
■ - INDICATES POSTS.
FOR SPACE APPLY TO
IRON & STEEL EXPOSITION
706- EMPIRE BL'DG.
PITTSBURGH, PA.

Association of Iron & Steel Electrical Engineers

BOARD OF DIRECTORS—1925

A. C. CUMMINS, President
Carnegie Steel Co., Duquesne, Pa.

G. H. SCHAEFFER, 1st Vice President
Carpenter Steel Co., Reading, Pa.

S. S. WALES,, 2nd Vice President
Carnegie Steel Co., Pittsburgh, Pa.

JAMES FARRINGTON, Treasurer
Wheeling Steel Corp., Steubenville, O.

R. S. SHOEMAKER, Past President
American Rolling Mill Co., Middletown, O.

R. B. GERHARDT, Past President
Bethlehem Steel Corp., Sparrows Point, Md.

W. S. HALL, Director
Illinois Steel Co., South Chicago, Ill.

A. J. STANDING, Director
Bethlehem Steel Corp., Bethlehem, Pa.

C. B. SKELLY, Director
American Steel & Wire Co., Cleveland, O.

J. E. HARRELL, Director
Tennessee Coal, Iron & R.R. Co., Fairfield, Ala.

G. R. McDERMOTT, Director
Illinois Steel Co., South Chicago, Ill.

F. W. CRAMER, Secretary
Bethlehem Steel Corp., Johnstown, Pa.

E. FRIEDLAENDER, Hon. Director
Pittsburgh, Pa.

A. I. & S. E. E. NATIONAL COMMITTEES FOR 1925

EDITING COMMITTEE

R. E. Lewis — F. G. Cutler — P. T. Vanderwaart — R. L. McIntosh

MEMBERSHIP COMMITTEE

Linn O. Morrow — W. W. Garrett — J. F. Kelly — A. R. Lintern
J. J. Booth — W. H. Williams

SAFETY COMMITTEE

R. S. Shoemaker — J. A. Morgan — M. W. Cobbledick — W. Greenwood
W. S. Hall — D. M. Petty — M. S. Robinson — L. R. Rankin
F. D. Egan — L. H. Burnett — F. L. Collins

REDUCTION OF INVENTORIES COMMITTEE

A. R. Leavitt — B. W. Gilson — J. C. Cooper — F. W. Cramer
A. G. Place — W. T. Snyder — H. E. Davis — R. L. McIntosh
C. W. Miller — C. A. Menk

STANDARDIZATION COMMITTEE

R. S. Shoemaker — F. W. Cramer — E. S. Jefferies — E. L. Upp
W. S. Hall — W. T. Snyder

COMBUSTION COMMITTEE

W. P. Chandler — S. Kneass — A. G. Witting — W. J. Harper
Walter Flanagan — G. R. McDermott — E. W. Trexler — C. H. Hunt
H. C. Siebert — F. G. Cutler — E. J. McLaughlin — J. C. Allen
A. Steed

PAPERS COMMITTEE

G. S. Proudfoot — F. O. Schnure — A. G. Place — R. M. Hussey
J. A. Morgan

ELECTRICAL DEVELOPMENTS COMMITTEE

W. S. Hall — C. M. Hickle — A. Alsaker — R. W. Davis
A. M. MacCutcheon — Ludwig Hommel — R. V. Bingay — H. F. Stratton
N. L. Mortensen — J. E. N. Hume — F. W. Jessop — E. S. Newton
J. R. Lewis — Brent Wiley

SPECIAL BEARINGS COMMITTEE

D. M. Petty — C. A. Menk — A. A. Stewart — F. A. Wiley
L. J. Hess — R. E. Lewis

IRON & STEEL EXPOSITION

G. R. McDermott
H. C. Siebert
C. H. Hunt
H. C. Mosley
A. L. Freret
A. J. Standing
J. C. Booher
S. L. Henderson
C. A. Menk
F. A. Wiley
E. T. Coates
V. I. Brinker
W. B. Connally
R. S. Sawdey
A. G. Place
A. Stewart
H. E. Davis
W. J. Harper

John F. Kelly, General Chairman

COMMITTEE ON GENERAL ARRANGEMENTS—20TH ANNUAL CONVENTION

Geo. H. Schaeffer, General Chairman

P. T. Vanderwaart
J. R. Penman
W. S. Hall
F. O. Schnure
F. H. Kitteridge

RECEPTION COMMITTEE

J. R. Penman, Chairman

T. E. Beddoe
John E. Brown
John P. Carothers
J. J. Edmiston
Thomas J. Fleisher
R. B. Gledhill
R. D. Gloeckner
H. K. Hardcastle
O. L. Holcombe
Walter C. Kennedy
H. A. Lewis
J. D. Marsh
Charles T. Moyer
Baxter Reynolds
Glenn M. Rumsey
D. F. Stakes
C. H. Williams
Geo. A. Kaufman

INFORMAL DANCE MONDAY EVENING

P. T. Vanderwaart, Chairman

R. L. Allewelt
Grant Armor
Allen B. Coffman
James W. Cryder
B. T. Hare
Wm. E. Harrison
Harry Hollis
Herbert Muehlberger
George Pfeffer
Kenneth M. Raynor
S. Russell, Jr.

REGISTRATION COMMITTEE

F. H. Kitteridge, Chairman

J. J. Booth
R. F. Chaffin
W. P. Chandler
F. E. Leahy
H. E. Davis
E. Swift Newton
R. M. Hussey
Thos. B. Little
E. S. Stickle
E. H. Martindale
A. H. Bergendahl
Norman Farrar
Louis Ellman
J. R. Lewis
J. J. Bangert
Geo. E. Stimple
A. W. Duncan
S. L. Henderson
A. L. Freret
S. Farrel
A. G. Pierce
Saul Lavine
E. A. Hurme
T. P. McGinnis
C. J. Mundo
W. L. DeCoursey
A. C. Dyer
B. J. Ballard
P. H. Schaum
A. B. Holcomb
Geo. Criss
Ray W. Davis
M. E. Skinner

INVITATION COMMITTEE

W. S. Hall, Chairman

W. P. Chandler
W. G. Suppler
R. H. Kiel
J. S. O'Donovan
W. Dyrssen
M. W. Cobbledick
Ray Davenport
W. Frank Detwiler
Barton R. Shover
J. C. Ritchey
F. D. Egan
C. H. Hunt
Wm. H. Ramage
L. C. Edgar
H. H. Laughlin
F. A. Wiley
A. Stewart
M. Robinson
Carl Landgrebe
C. S. Proudfoot
S. S. Wales
E. S. Jefferies
S. M. Johnston

DINNER DANCE THURSDAY EVENING

F. O. Schnure, Chairman

R. L. Baker
H. S. Boone
Edward P. Burns
H. D. Esterly
Linn O. Morrow
D. M. Petty
John C. Reed
G. W. Richardson
George A. Rumsey
A. J. Standing
G. J. Walz

W. FREELAND KENDRICK
MAYOR

EDWARD LOEB
SECRETARY

CITY OF PHILADELPHIA
OFFICE OF THE MAYOR

September first, 1925.

Association of Iron and Steel
Electrical Engineers,
Philadelphia, Pa.

Gentlemen:

As Mayor of the City of Philadelphia, it gives me great pleasure to welcome your Convention to our City.

You gentlemen of the Association of Iron and Steel Electrical Engineers are in close touch with the thought and genius which man has wrought in iron and steel, and who by electricity has astonished the world by the marvelous achievements in the last half century.

Next year, we will celebrate in Philadelphia, the 150th Birthday of our Nation with a Sesqui-Centennial celebration. Fifty years ago, Philadelphia celebrated the 100th Birthday of the Republic with a Centennial. In the fifty years that have elapsed, no phase of American achievement, of which we are all justly proud, can surpass the enormous growth of the iron and steel industry and the tremendous strides made in electrical engineering. Philadelphia is proud of the part she has played in this splendid work.

On behalf of those who here abide, I extend cordial greetings to all of you and welcome you to the City of William Penn and the Liberty Bell.

Very truly yours,

W. Freeland Kendrick

MAYOR.

EDITORIALS

THE ENGINEER IN INDUSTRY

By A. C. CUMMINS*

THE best opportunity to observe the operation of the many activities of the Association of Iron and Steel Electrical Engineers is undoubtedly reserved for those who have been given the honor of serving as its President. Each year sees expansion in the scope of the Association's activities. And as I review the accomplishments of the past, I cannot help but feel that the Association has been going through an evolution in its work, which is reflecting the greater consideration which has been given to the value of the engineer in industry.

Since the very beginning, the American industrial machine has expanded quite rapidly. While there

A. C. CUMMINS.

have been periods of depression, the development has been made in such an orderly manner that the demand for industrial products soon overtook the supply and, therefore, such periods, were of comparatively short duration. When the World War came along, this orderly industrial expansion changed to one of very extensive and rapid growth. A demand for industrial products was suddenly created far in excess of anything hitherto anticipated. As a result, the capacity of our industrial machine was tremendously increased and its ability to produce became far greater than was necessary to supply the domestic demand. The conclusion of the World War eliminated the abnormal demand and manufacturers found themselves with modern plants equipped with expensive machinery, capable of producing a greater volume of product than would likely be required for a number of years. When the period of readjustment set in, keen competition for domestic business resulted, and it was only the plants where the most modern labor-saving devices were in use and possessing a personnel trained in its efficient use, which were able to operate at a profit

It has been through this period of depression that the engineer has been called upon to fill a more important role in the management of our manufacturing establishments. He has been required to design new devices for saving labor, new means of economizing in the use of raw materials and better methods of operating equipment already under his supervision. At the very outset of this period, executives discovered that fuel was rapidly assuming great importance in determining the cost of production. In some industries more money was spent for fuel than for all other raw materials combined. This was notably true in the metallurgical field and consequently all progressive plant managers were on the lookout for ways and means of economizing in its use. Before long the fuel engineer appeared on the horizon and he was so successful in assisting the metallurgical and central station industries in reducing their fuel costs that he is now firmly intrenched in every industrial organization where fuel is a factor in the cost of production.

During the past two years the steel industry has experienced strenuous competition. It is well known that in any industry only the plants which operate most economically carry full production schedules in periods of depression. It is interesting to note that during the periods of depression in the steel industry during the past few years, that the plants most completely equipped electrically are the ones operated at maximum producing schedules. Does this not demonstrate beyond all question that the claims electrical engineers have made for the economy and reliability of universal electrification have stood the acid test of practice and have not been found wanting? Does it not reflect great credit on the electrical engineers of the steel industry, especially those who have been responsible for the general adoption of electricity throughout our mills?

The members of our Association are to be congratulated for their progressive attitude during the development of the use of electricity in our mills. They have seen the possibilities of greater responsibility for engineers in saving fuel, in designing equipment to save labor, and to improve operating

*President A. I. & S. E. E., Elec Supt. Carnegie Steel Company, Duquesne, Pa.

Executive Officers, Philadelphia District Section, Association of Iron and Steel Electrical Engineers, Who Will Look After Your Convenience and Comfort While Their Guest At Philadelphia.

G. J. WALZ,
Asst. Elec. Supt. Steelton Plant, Bethlehem Steel Company, Steelton, Pa.
Executive Committeeman, Philadelphia Dist., A. I. & S. E. E.

FRED O. SCHNURE,
Elec. Engr. Bethlehem Steel Company, Sparrows Point, Md.
Executive Committeeman, Philadelphia Dist., A. I. & S. E. E.

H. SEARLES BOONE,
Shoemaker Bridge Company, Pottstown, Pa.
Chairman Philadelphia Dist. A. I. & S. E. E.

LYNN O. MORROW, Secretary,
Philadelphia District Section, A. I. & S. E. E.

GEORGE PFEFFER,
Florence Pipe Foundry & Machine Company, Florence, N. J.
Executive Committeeman, Philadelphia Dist., A. I. & S. E. E.

methods. They have been quick to see the opportunities for improvement and to call upon their Association to serve them in a broader way in order that they might be fully equipped to carry on this enlargement of their work. One of the results of this foresight was the formation of our Fuel Saving Section. I feel it is filling a very great need for the membership by supplying a better acquaintanceship with the fundamental problems of economy in the use of fuel. The Fuel Savings Conferences successfully introduced to many the details of the problem as well, and it is to the records of the activities of this Committee that all look for authoritative information on what is newest and best in this great field for saving money. A similar demand has been responsible for the activities of the Electric Heat Committee. Their accomplishments have been almost as comprehensive in their scope, as it is possible to find in their proceedings answers to many of the electric heating problems of the day. It will be found that there are new fields for effecting economies by adoption of electric heating in nearly every industry, which have not been previously appreciated, and that the possibilities for improvement in the quality of our products by its adoption may lead to many changes in industrial processes in the future. It is to be hoped that the Committee will continue in its work, and keep fully awake to the possibilities of achievement in this line.

One of the most difficult questions now facing our Association is the solution of the problem of standardization. Progress in the art of applying electricity to industry has advanced so rapidly that it is difficult to stop long enough to standardize on one class of equipment before a new development proves so vastly superior that all thought of standardization is dropped in the haste to install what is newer and better. However, I believe the possibilities in the field of standardization have been overlooked and the future will see standardization adopted in a way which will not handicap the development of still better and more economical equipment, yet accomplish much towards the goal of interchangeability and duplication for which all operating engineers so diligently strive.

All of these activities indicate that the engineers are becoming a greater factor in the management of our industries and well they might be, as their training has especially fitted them to analyze its problems, and to use common sense in applying what their analysis has determined. In the steel industry, particularly, engineers have been called upon to make accurate decisions quickly and the result has been that they are not only trained to analyze the problems of industry and to use common sense in applying the results to their analysis, but, also, in possessing the courage to proceed once their decision is made. Too often in the past the questions of management have not been solved on a careful and logical basis; and it is to be regretted that many of our industrial failures have been due to the lack of the proper method of procedure. One of the most encouraging signs of the times is to find that the men at the heads of our large enterprises are becoming more and more dependent upon the engineers of industry for consultation and advice before making important decisions of management. This policy cannot help but mean that our plants will be managed more economically, more logically, and more justly than in the past.

It has been said that engineers have done little towards the solution of the social problem of our industrial enterprises, but they have done much to advance the progress of industry in a technical way. In other words, the engineer has been charged with devoting his time to improving processes and to solving problems of economizing in the use of labor, but has accomplished little toward helping the growing question of the relation between the worker and the management. Perhaps this is true. But it has also been said that the real indication of the degree of civilization of a country is the wages that it is paying to its workmen. There is nothing impossible about a high wage and low costs. It is only necessary to see that high wages are more largely productive. The problem of making wages more productive is entirely one for the engineers. Because it is to him that American industry owes the introduction of automatic machinery, and all the various labor-saving devices, and to improvements in the processes of production. It is a constructive thing to eliminate human labor, to replace it by machinery, and to the engineer society owes more than it can ever repay for the progress that has been made in this field. It is also true that where wages are low the standard of living is low, and I think the American working man owes more to the engineers of industry for his ability to purchase his comfortable home, and ride in his automobile, than to any other one agency of improvement. And, therefore, it does not seem improper that the engineer should be receiving greater recognition in industry, as his records of achievement justify a much greater importance than he is now receiving. However, in order to gain that final recognition which ability, training and intelligence justify, the engineers must actively engage in solving the problem of establishing better relations between labor and management so that the workmen of our industries will find greater pleasure in their work, and receive remuneration entirelycommensurate with the service they are rendering. And when the engineer has been successful in solving this great problem, there is no question that he will have made his greatest contribution to the welfare of American Industry, and to the welfare of his fellow-citizens as well.

OUR TWENTIETH ANNUAL CONVENTION

By R. S. SHOEMAKER*

TO THE members of the A.I.S.E.E., who are now making plans for attending the annual convention and exposition to be held at Philadelphia this month, would it not be well to consider one way in which the best interests of the Association might be promoted?

Your attendance at all technical sessions will contribute immeasurably to their success. Although you may not be vitally interested in the subject presented, your presence will be an added stimulus to the author delivering the paper. It is not fair to him after he has spent weeks collecting data, then to be subjected to that hardest possible task, of addressing empty chairs, instead of the pleasure and

*Supt. Maint. Depts., American Rolling Mill Co., Middletown, Ohio.

FRANK H. KITTREDGE,

Elec. Engr. Illinois Steel Co., Joliet, Ill.
Chairman, Registration Committee.

C. S. PROUDFOOT,

General Mgr. United States Ferro Alloys Company, Niagara Falls, New York.
Chairman, Papers Committee, 20th Annual Convention, A. I. & S. E. E.

GEORGE H. SCHAEFFER,

Carpenter Steel Company, Reading, Pa.
Chairman, Committee on Arrangements.

A. J. STANDING,

Supt. Elec. Dept., Saucon Plant, Bethlehem Steel Company, Bethlehem, Pa.
Chairman Rules & Regulation Committee, 20th Annual Convention, A. I. & S. E. E.

F. R. CHAFFIN,

Elec. Engr. Pittsburgh Crucible Company, Midland, Pa. Chairman Ticket Committee, 20th Annual Convention, A. I. & S. E. E.

satisfaction always derived from an audience such as our large membership should assure.

Reading a technical paper either before or after the convention compares in no way with being present at the delivery and hearing and participating in the discussion.

Think back to other convention years. Did you not derive the greatest benefit from the technical sessions, with the intimate personal contacts formed at that time?

Did not the personal friendships which we all value so highly have their beginning at that time or during the private discussions which always follow the breaking up of each meeting?

Having been in attendance at practically all conventions from the early days when we could count our membership by the dozens instead of as now by the hundreds, I believe I can answer yes to both questions without fear of contradiction.

So, then, as we make our final traveling arrangements let it be with the firm resolve that we will do everything in our power to make the technical sessions the outstanding success they must be if the work of this Association is to continue to be of an unquestionable value to the Iron and Steel Industry that it has been in the past.

This year's Paper Committee, under the very able chairmanship of Mr. C. S. Proudfoot, has prepared a program which will be of widespread interest to all members and to the engineering world at large.

MECHANICALLY TRAINED ELECTRICAL MEN

By W. S. HALL*

THE development of electrical apparatus commonly found in steel mills has been very pronounced when considering what can be purchased today compared with that supplied 15 years ago. This statement is particularly true in regard to small motors and control for auxiliary drives. It is at the present time a pretty well established fact that if a study is made of the motor and control from the standpoint of a duty cycle that the application can be made nearly 100 per cent perfect. This leaves therefore only the human element as the determining factor between the successful and the unsuccessful drive. This enters into the proposition in three different places; first, the engineer in charge of the application; second, the man in charge of the operation of the equipment and third, the man in charge of the maintenance of the equipment.

Close co-operation between the three different classes mentioned above is necessary for successful operation. The development and training of engineers who are capable of making the proper control and motor application has been very rapid. To a certain extent recent developments in automatic control have eliminated the operator as one of the important factors, leaving the maintenance man as the most important factor in connection with the successful operation of auxiliary equipment.

Experience has shown that where the control and motor are properly applied, electrical troubles which have developed are generally caused by faulty mechanical design or maintenance in the apparatus which the motor drives. It is, therefore, of the utmost importance to have close co-operation between mechanical and electrical maintenance men. So important is this that considerable progress has been made toward developing men with both mechanical and electrical experience. The question of divided responsibility will always be present until such a time as both mechanical and electrical supervision are under one man. This practice is being adopted more and more, as fast as the experienced men can be developed, and it is felt that it is the only solution of the maintenance problem. With this in mind it appears highly important, since the successful apparatus can now be purchased, that the steel plant electrical superintendent devote more and more time to the development of this type of men and eventually wipe out the old established deadline of responsibility.

*Elec. Engr., Illinois Steel Co., So. Chicago, Ill.

THE ANNUAL CONVENTION POWER SHOW

By S. S. WALES*

SEPTEMBER is the month of our Annual Material Convention, where it is intended to give the technical papers a broader field than those at the monthly section meeting so as to interest members from widely separated districts, and take advantage of discussion by the nation wide representation which we expect to have. It is at these annual conventions also, that we meet and exchange views with many old friends and acquaintances with whom we do not come in touch at any other time.

This year the Convention is to be held in the historic city of Philadelphia, and it is hoped that there will be a large attendance, and the usual active interests in the exhibits which make up the "Power Show."

Aside from the technical and social side of this meeting, the association endeavors to assemble and exhibit each year, in compact and attractive form, the most up-to-date material, equipment, and tools which can be found on the market, so its members may see and learn the most approved and latest methods of meeting the emergencies, which continually confront them in their daily routine, and which on account of this routine, may not have received their particular attention.

As we walk through the building with booths arranged in orderly lines, with material and equipment on display, and a representative of the manufacturer anxious to explain the value of his product and improvements made, it seems very simple, but to assemble, organize, and run this "Power Show" is by no means an easy task, and would be impossible but for the service given by our manager and some of our members.

It is, of course, not possible for all to attend this meeting and the question sometimes arises, as to the benefit to the man, and the value, to his firm, to be derived, to balance the time and money cost of those who go.

In trying to answer the question as to the value of the exhibits to our members, an analysis of the coming show from a Pittsburgh viewpoint may be instructive. We have a total of eighty-one exhibitors of whom sixty-six are outside of Allegheny

*Chief Elec. Eng., Carnegie Steel Co., Pittsburgh, Pa.

E. A. HURME,

Manager Steel Mill Division Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa. Author, 20th Annual Convention, A. I. & S. E. E.

J. A. SEEDS,

Elec. Engr. General Electric Company, Schenectady, N. Y. Author, 20th Annual Convention, A. I. & S. E. E.

GEORGE H. BURNHAM,

Engineering Dept., Condit Elec. Mfg. Co., Boston, Mass. Author, 20th Annual Convention, A. I. & E. E. E.

W. H. POWELL,

Elec. Engineer, Allis Chalmers Company, Milwaukee, Wis. Author, 20th Annual Convention, A. I. & S. E. E.

A. L. PENNIMAN,

Supt. Steam Stations, Consolidated Gas Electric Light & Power Co., of Baltimore, Md. Author, 20th Annual Convention, A. I. & S. E. E.

F. W. QUARLES,

Asst. Supt. Steam Stations, Consolidated Gas Electric Light & Power Co., of Baltimore, Md. Author, 20th Annual Convention, A. I. & S. E. E.

County, coming from Massachusetts, Connecticut, New York, New Jersey, Maryland, Georgia, Pennsylvania, Ohio, Illinois, Michigan, and Wisconsin, eleven states, and reaching from Boston to Atlanta, Milwaukee to Cincinnati and New York to Chicago. To make a single trip from Pittsburgh to each of the twenty-five cities represented would require a travel of more than eighteen thousand miles at a cost of six-hundred and fifty dollars for railway fare alone, and an absence from work of at least twenty-five days.

All this is concentrated at one point for five days' displays, and by taking advantage of the opportunity offered by the Convention and Power Show, a very good return should be made on the cost, in both time and money.

THE VALUE OF THE IRON AND STEEL ENGINEER

By W. DUDLEY*

We members of the Association of Iron and Steel Electrical Engineers in common with most busy folks in other walks of life, are prone to accept as a matter of course, many of the useful things with which we are supplied, and perhaps never give a thought as to how much they are worth to us. So when a friend wrote me a few days ago and asked me what value the Iron and Steel Engineer might be to the steel industry, I was stumped and at a loss to place an estimate on its value. The monthly visit of this publication to my desk has always been so welcome, and each issue has held so many articles of interest and value to me personally, that I never gave any thought as to its worth to the steel industry at large, nor how other readers who are not connected with the Association might consider it. So that we may have at least some idea on the subject, it will not be amiss to give it a little of our thought and try to set forth in a few brief paragraphs some of the methods by which it does serve the steel industry.

The three major activities in the production of iron and steel with which the Association now concerns itself are: The generation and application of electricity, the combustion of fuels, and the generation and use of steam. The essential part played by these three factors in the production of iron and steel are as vital to the successful operation of a blast furnace or steel plant as the stomach, arterial system and lungs are to the human body. To them it is only necessary to add men, mills and materials, and there would be assembled the main factors in the gigantic job of producing the world's requirements of iron and steel. So if we can set forth some measure of the extent to which the Iron and Steel Engineer directly stimulates the improved use of electricity, fuels and steam in the production of iron and steel and indirectly influences the mills and the men who operate them, there can be little doubt of the value of this publication to the steel industry at large.

In the actual production of steel during the last twenty-five years, it is no exaggeration to state that electricity has taken a most prominent part in reducing costs, improving processes and increasing tonnage. With its low cost of generation, its ease of distribution, its nicety of control and its unlimited power in main or auxiliary drives and in other accessories, it has practically revolutionized the rolling methods in use at the beginning of this century. This result was not accomplished without mighty effort on the part of pioneer manufacturers, and electrical men who met stiff opposition all along the way. But as fast as successful application was made and the economy and merit of the new force was established the results were broadcast through the proceedings of the Association to a waiting and confident group of other electrical men, who armed with the published and authentic results, were able to convince other managements of the desirability of utilizing this new force. The mere fact of publication and written discussion with its inherent ability to uncover errors or unwarranted claims gave definite knowledge to many men and with the knowledge came the power to persuade others of the merit of electricity. No one conversant with the industry can doubt the wide influence which these articles have exerted during the last eighteen or twenty years. There is hardly an electrical application of importance in the steel industry but what has been covered many times and by many able men in the pages of the Iron and Steel Engineer.

What has occurred with electricity during the past two decades is now being duplicated in the articles on combustion of fuels and generation and use of steam which are appearing in practically every issue of the Iron and Steel Engineer during recent months. It is no idle boast to state that the articles thus presented when measured in their value to the solution of practical operating problems and economics in the iron and steel industry are not excelled by those presented in the pages of any American technical publication dealing with fuels and with steam. It is realized that there is a voluminous literature on these two subjects and the fundamental principles applying to each have been ably presented by many distinguished men in numerous textbooks and articles, but none of these have put these principles in more plain, practical, usable form than those men who have written for the Iron and Steel Engineer. Just as the electrical men have done before them, the fuel and steam men have worked out their problems in as simple and practical a manner as possible and then have published the facts, figures and results as applying to the general problems of the steel industry, thereby enabling other busy steel men to analyze and compare with their own conditions and the more readily reach a solution of their own problems.

Comparisons are odious, as has been well said, and it is not necessary in this short article to mention outstanding papers dealing with these three subjects which have appeared in past issues of the Iron and Steel Engineer. To the man who is interested or who wants information on a specific subject it is only necessary to refer to the former volumes for proof. There are now being published probably seventy-five papers a year and practically every major problem or outstanding development in electricity, fuels or steam will be capably handled in one or more of them before the year is completed. In addition to this there will be other articles and items on lesser subjects which will reach the attention of the alert engineer or operating man and provide him with information and inspiration to assist in reducing costs, improving processes or increasing tonnage.

*Elec. Engr., American Rolling Mill Co., Ashland, Ky.

HENRY A. RENNINGER, Asst. Pres.
Lehigh Portland Cement Co., Allentown, Pa.
Vice Pres. National Safety Council

JOHN OARTEL,
Chief of Safety Bureau, Carnegie Steel Co., Pittsburgh, Pa. Author, 20th Annual Convention, A. I. & S. E. E.

G. M. ALBRECHT,
Elec. Engr., Allis Chalmers Mfg. Co., Milwaukee, Wis. Author, 20th Annual Convention, A. I. & S. E. E.

Hon. W. FREELAND KENDRICK,
Mayor of Philadelphia

S. S. WALES,
Chief Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa. Author, 20th Annual Convention, A. I. & S. E. E.

W. P. CHANDLER,
Special Engr. Carnegie Steel Co., Pittsburgh, Pa.
Chairman, Combustion Engrg. Section, A. I. & S. E. E.

For each steel mill engineer who has been directly assisted in making improvement in his equipment by the information thus obtained, there must be many others of his associates who have been inspired by his results and by the improved facilities thus made available to re-design his machine, or change his process, or re-arrange his organization in order to obtain the greatest possible benefit. Achievement begets confidence in men and once an organization grasps the essential factors necessary to overcome difficulties and has an opportunity to learn what others are doing and the results they obtain, the effect is cumulative and frequently they are able to accomplish far more than they would have cared to predict when they started. The sign posts on the road to successful accomplishment have been set up so many times by the pages of the Iron and Steel Engineer that the record speaks for itself. More and more its articles are referred to for data and guidance by even non-members of the Association which is a very certain evidence of its value.

In the last analysis of course it is upon the men of an organization, rather than upon its resources or equipment, on which its prosperity and success depends. The better informed the men of the steel industry become and the more they are stimulated to improve and advance the activities for which they are responsible, the more certain and sure will be the future standing of the steel industry of America in comparison with that of other nations. Surely no publication within my knowledge has reached a greater number of trained, alert technical men employed in the steel industry than has the Iron and Steel Engineer. As it has furnished them with information in usable form just to that extent has it served the steel industry. In my judgment its influence has been tremendous and can hardly be estimated in any definite value. This much may be said, however, that were its great value not recognized by the members of the Association it would have ceased to exist long ago. There are but few features connected with the steel industry which continue to exist after their economic value has vanished. On the contrary, the Iron and Steel Engineer and its parent, the Association, were never in more flourishing condition than at present, and this must be due to the very valuable service which they render to a large group of representative men who are using their time and talent in the advancement of the steel industry. To the extent that these men are a valuable asset of our steel industry so may the value of the Iron and Steel Engineer be measured. It has given to a very large number of them both the information and inspirations which have necessarily been a large factor in enabling them to advance their work from its position of minor influence some twenty-five years ago to its present position of activity and major responsibility.

It is their medium of expression and with its help they continue to enjoy a prominent part in stimulating and improving the producing end of the iron and steel industry.

OUR PERIODICAL

By R. F. CHAFFIN*

It is confidentially believed that no other periodical contains to the same complete degree the class of information which is being published in convenient form in the Iron and Steel Engineer. The editor in his able way avoids generally the formality associated with a strictly technical work. A procedure that finds considerable favor with the busy executive, while at the same time, proving a valuable aid to the electrical mechanical, combustion and chief engineers.

The semi-catechetical form often used in presenting discussions of papers appeals strongly to the practical man who wants a simple answer to a plain, practical problem as well as an exposition of the principles involved.

The Iron and Steel Engineer in its present form, as conceived by our incomparable National Secretary, is serving as a convenient medium between the manufacturers and users of appliances and equipment in the manufacture and shaping of iron and steel.

Let us, as well as you, Mr. Manufacturer, on the eve of what promises to be the greatest convention held by our Association, in a year blest with exceptional and merited success, not be unmindful of the enormous credit due to the Iron and Steel Engineer, our periodical.

*Supt., Electrical, Steam and Hydraulic Depts., Crucible Steel Company.

COMBUSTION SECTION A. I. & S. E. E.

By W. P. CHANDLER, JR.*

The Combustion Section of the Association of Iron and Steel Electrical Engineers is five years old. During this period the section has grown to a membership of 105. This growth has been proof of the desire of the industry to interchange ideas so that all may reduce the enormous consumption of fuel which is required for the production of the finished steel product. Realizing this desire the Combustion Section has conducted annually a fuel saving conference, at which the fuel engineers of the iron and steel industry discuss the leading problems of the year and compare the results obtained with various methods of equipment. The ideas obtained in such manner invariably allow improvements to be obtained in the individual plants after they have been tried out and perhaps modified to suit existing conditions.

Each year brings forth its crop of fuel saving inventions of varying merit. These must be carefully digested and the good separated from the bad. New equipment is constantly being offered for sale and in many cases is tried out in one or more plants. However, a great deal of money could be saved if a short statement of results of the various trials were made available for the steel industry in general.

A compilation of such reports could be undertaken by this section of the association if the companies comprising the steel industry were willing to co-operate. The value to the industry as a whole would be very great and much time and money could be saved by preventing the necessity of innumerable trials of the same character in separate plants.

The association of the Central Power Stations long ago realized these facts and today the report of the Prime Movers Committee of the National Electric Light Association amply justifies the time and expense. And the broad minded policy of the member companies

*Special Engr., Carnegie Steel Co., Pittsburgh, Pa.

A. R. LINTERN, Secretary,
Cleveland District Section, Floor Manager,
Iron and Steel Exposition.

R. S. SHOEMAKER,
Supt. Maint., American Rolling Mill Company, Middletown, Ohio.
Chairman, Technical Session, Friday, September 18, 20th Annual Convention, A. I. & S. E. E.

W. H. WILLIAMS, Secretary,
Chicago District Section

JAMES FARRINGTON, Treasurer,
A. I. & S. E. E.

W. S. HALL,
Elec. Engr. Illinois Steel Company, So. Chicago, Ill.
Chairman, Committee on Invitations, 20th Annual Convention, A. I. & S. E. E.

has returned a goodly sum of money to their individual treasuries.

Would it not be of immense value for this association to institute a similar report for the iron and steel industry? Fuel engineers all over the country are confronted with the same problems, and past experience of fellow members would often be of great assistance in arriving quickly at a decision.

Comments from members on the feasibility and value of the scheme as outlined are requested by the editor and chairman of the Combustion Section.

THE FUTURE OF ELECTRICITY IN THE STEEL INDUSTRY

By W. H. BURR*

To review what has happened in the past is to write history, to predict what will happen in the future is to prophesy. The ability to prophesy is given to but few; it is possible, however, by carefully analyzing past events to predict with a certain degree of accuracy what we may expect to accomplish in the future. If we stop and consider the growth of the steel industry in the United States and also bear in mind the increase in HP. used on main roll drives during this same period we can with a certain degree of accuracy visualize the future of Electricity in the Steel Industry.

The annual output of steel in the United States has increased in twenty years from twenty to over forty million gross tons. This has not been a steady growth; for the steel industry is noted for its fat and lean years. During this same period the total HP. installed on main roll drives has increased steadily from a single unit until we now have over fifteen hundred thousand HP. in motors driving mills in the United States. This means that 50 per cent of all the mills in the United States are motor driven at the present time. From this is it unreasonable to predict that twenty years from now all the main rolls in the United States will be motor driven?

The design of automatic control equipment has kept pace with motor design and automatic substations are operating satisfactorily. When the same amount of time and energy has been expended on the design of automatic control on mills as has been expended on the design of automatic substation equipment I believe we can expect to see the roller press a key board fixing the reduction on the different passes after which the mill will automatically deliver the finished product.

One of the items of expense in connection with the operation of steel mills which is receiving consideration at this time is that of yard switching. The design of internal combustion engines has reached a stage where reliability is assured and it is only reasonable to expect that when used with generators and motors on yard switching locomotives we will obtain economies in keeping with those obtained when motors were installed in place of steam engines on auxiliary drives in the steel mills. In order to accomplish what has been visualized it will be necessary to continue to improve on the design and application of electrical equipment in our mills as has been done in the past.

*Elec. Supt., Lukens Steel Co., Coatesville, Pa.

The successful operation of electrical equipment in the steel industry is due largely to the co-operation of designing engineers and the engineers of the steel industry. This spirit of co-operation has been fostered by the A. I. & S. E. E. for twenty years and it is the earnest desire of this association that this co-operation may continue and by so doing make it possible to accomplish even greater things for the steel industry in the future than have been accomplished in the past.

COMBUSTION CONTROL OF OPEN HEARTHS

By J. M. CONWAY*

THE days of optical control of the combustion in an open hearth furnace are fast drawing to an end as the economic production of quality steel demands not only the minimum consumption of fuel in its production, but also the introduction of labor-saving devices which allow the furnace man more time to be given to the real task at hand, that of the refining of the metal in the bath.

That phase of the open hearth process which lends itself most readily to automatic control is the feeding of the fuel and air for combustion. Because of the various fuels and combination of fuels at present in use, there are a large number of controlling devices on the market, each having its own individual merit and the purpose of this article is to point out the fundamental principles that should govern their design and use rather than enlarge on the merits of any one particular design.

The types of fuel in common use are—bituminous producer gas, coke oven gas, coal tar, oil and in some cases natural gas.

The table shown herewith gives comparative values both in B.t.u and prices for these various fuels.

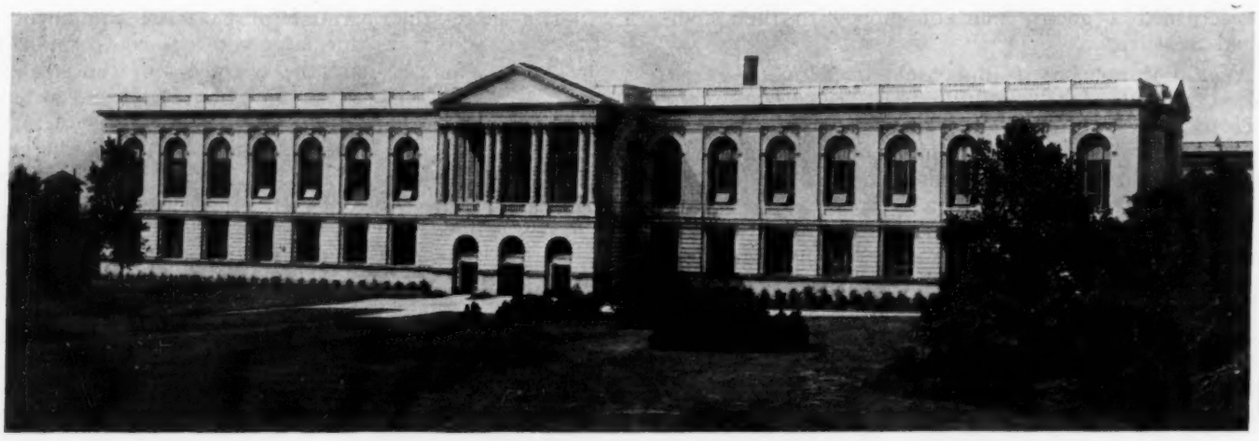
Dealing with these fuels in the order mentioned, producer gas is undoubtedly the most used open hearth fuel today and will hold a place in this branch of the steel industry for some time. The type of control, which produces the best results in the gas house, is the control which delivers to the furnace a gas of constant B t.u. content, thermostatic control of the gas production being at present the best means of obtaining gas of a nearly constant B.t.u. value, or in other words, the use of a recording pyrometer at the outlet of the gas producer and the production of gas of a constant temperature, this temperature will vary with the type of producer.

The valve operating mechanism at the furnace should be so arranged that a change in the gas volume would be automatically compensated by a change in the air volume, this coupled with gas pressure control would insure at all times a correct mixture of fuel gas and air immaterial of the furnace demand.

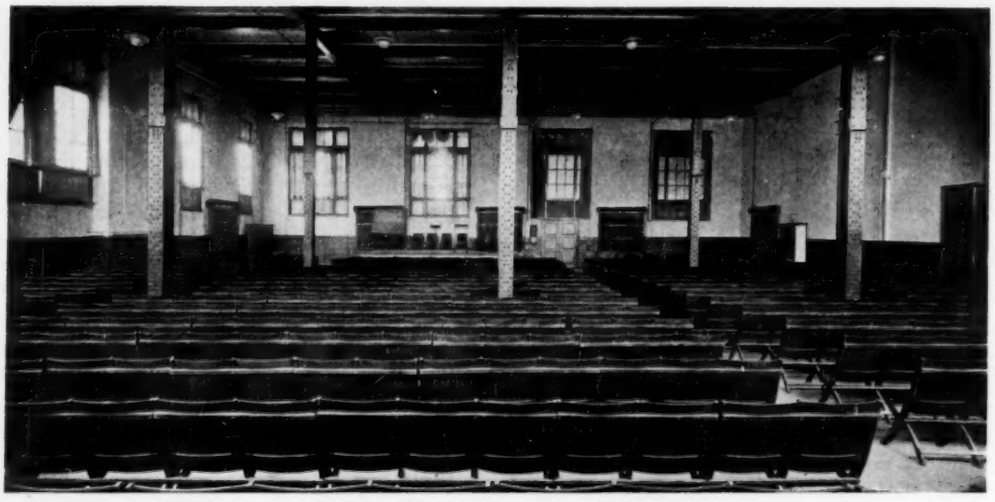
Coke oven gas is comparatively easy to control but has not received the thought that should have been given to the economic use of this valuable gas.

Coke oven gas has an average value of 550 B.t.u. per cubic foot and is probably the cheapest open hearth fuel we have at this time, yet had we have given this gas the careful attention ordinarily be-

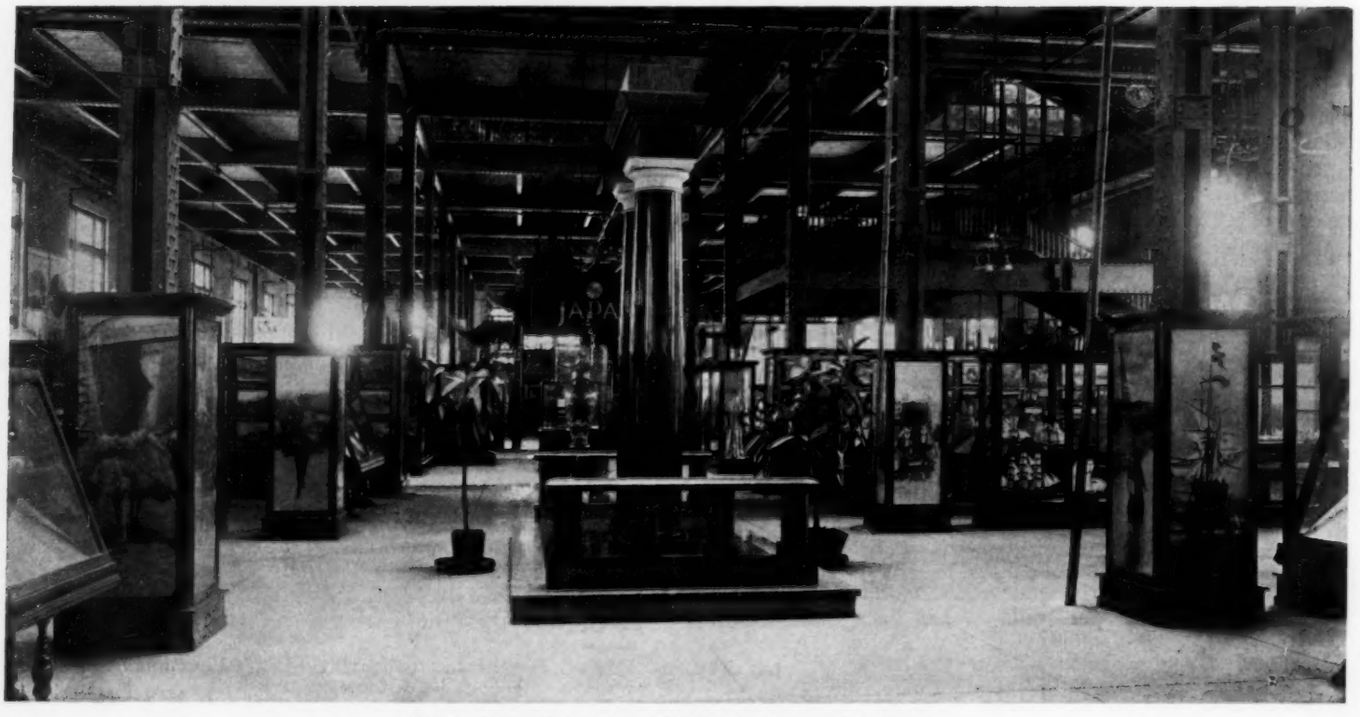
*Fuel Engineer, Steubenville Plant, Wheeling Steel Corporation, Steubenville, Ohio.



Philadelphia Commercial Museum



Lecture Room, Philadelphia Commercial Museum



Interior View, Main Bldg., Philadelphia Commercial Museum

stowed upon the combustion of blast furnace gas, which has approximately one-sixth the fuel value, the fuel cost of ingot production where coke oven gas is in use would be appreciably decreased.

The first feature in the control of coke oven gas combustion is the delivery to the furnace of a gas at a constant pressure independent of the amount consumed, the mercury sealed, balanced, pressure reducing valve is probably the best suited for this service.

We have been shown by recent developments in the open hearth that it is possible to control the amount of air in proportion to the quantity of gas and so obtain very low B.t.u. consumption per ton of steel produced.

Steel plants having a surplus of coke oven gas for use in the open hearth should avail themselves of proportional control for the combustion of this fuel, also, this gas can be practically freed of sulphur by addition of suitable equipment at the coke plant at a comparatively small cost.

Coal tar and fuel oil can be similarly controlled. The essential factors being the control of the pressure and temperature of the fuel up to the point of atomization and pressure control of the steam where it is used as an atomizing medium. These pressures and temperatures should be maintained constant without regard to the amount used and the quantity should be controlled by increasing or decreasing the size of the orifice through which the fuel and atomizing medium pass to the atomizer.

Fig. 1 shows a viscosity curve determined on a typical coke plant tar at various temperatures. From the curve it will be readily seen that the viscosity is practically the same at 150°F as at 200°F, therefore to heat the tar above 150°F will not aid its atomization and will also waste valuable heat units in the form of steam supplied to the tar heater.

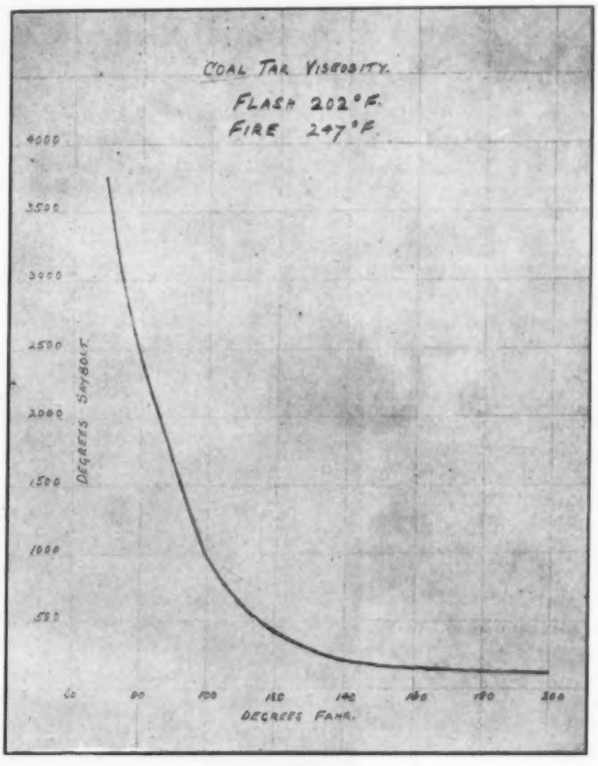


FIG. 1.

OPEN HEARTH FUELS

AMOUNT OF DIFFERENT FUELS FOR EQUAL HEAT UNITS

OIL	TAR	COAL	NATURAL GAS	COKE OVEN GAS	TOTAL B. T. U.
Gal.	Gal.	Lbs.	Cu. Ft.	Cu. Ft.	
1.	.84	13.5	135	245	135,000
1.185	1.	16.	160	291	160,000
148.	125.	2000.	20000	36394	20,000,000
7.41	6.25	100.	1000	1818	1,000,000
4.07	3.44	55.	550	1000	550,000

In the comparison of B. T. U. values the coal is figured as 12,500 B.T.U. per pound with an 80% gasification efficiency at the producers or 10,000 B. T. U. per pound of coal gasified as being delivered to the furnace.

COST OF DIFFERENT FUELS FOR EQUAL HEAT UNITS

USING 6,000,000 B. T. U. PER TON

PRICE OF COAL PER NET TON

	$2.50	$2.75	$3.00	$3.25	$3.50	$3.75	$4.00	$4.25	$4.50	$4.75	$5.00
OIL—gallon	.025	.027	.028	.030	.032	.033	.035	.037	.038	.040	.042
TAR—gallon	.030	.032	.034	.036	.038	.040	.042	.044	.046	.048	.050
NATURAL GAS—1000 cu. ft.	.208	.221	.233	.246	.258	.271	.283	.296	.308	.321	.333
COKE OVEN GAS—1000 cu. ft.	.115	.121	.128	.135	.142	.149	.156	.163	.170	.176	.183
PRODUCER GAS—600 lbs.	1.250	1.325	1.400	1.475	1.550	1.625	1.700	1.775	1.850	1.925	2.000

All prices F. O. B. the plant. Included in the producer gas item together with the cost of coal is the cost of unloading the coal from the shipper's vehicle, crushing, loading into intermill cars and transporting to gas producers; cost of labor, steam, power, light, water, repairs and maintenance. The figure used is fifty cents $0.50) per ton of steel.

In comparing oil and tar cost an allowance of fourteen cents ($0.14) per ton of steel was made for labor in unloading tank cars and delivering oil to furnace together with the cost of steam used in heating, pumping and atomizing.

VALUES USED PER TON OF STEEL

OIL	44.44	gallons
TAR	37.5	gallons
NATURAL GAS	6000	cubic feet
COKE OVEN GAS	10909	cubic feet

Independence Hall

The Old State House, the Nation's first Capitol, situated on Chestnut Street between 5th and 6th, is the most famous historical building in America. Here the Declaration of Independence was debated and signed, and the Constitution of the United States adopted. The foundation of this building was laid in 1729 and the structure completed in 1735. It was here the famous old Liberty Bell, the Nation's most precious relic "Proclaimed liberty throughout the land." The building contains many interesting relics of Revolutionary days.

Washington Monument
Fairmount Park
Green Street Entrance
The finest bronze group in this country

Lincoln Monument
Fairmount Park
Near Green Street Entrance

However, should the temperature of the tar drop to 90°F, the tar becomes sluggish and atomization is not complete which entails a fuel waste. Fuel oil and tar, because of their concentrated B.t.u. value, are more easily wasted than any other open hearth fuel and if the temperature of these fuels is not controlled, atomization is retarded and waste of fuel results. Therefore, the steel plant which is equipped with the devices described can manufacture steel at a lower fuel cost than another plant not so equipped, also allowing the furnace men more time to give to the production of better quality, providing, of course, that the control equipment is receiving the necessary care and attention.

The introduction of control equipment in an open hearth means the introduction of skilled labor for the upkeep and repair of this equipment, but a properly organized shop can not only keep the total number of men employed within the quota, but in all probability make a tangible reduction. Fuel to all furnaces should be metered to check the performance of the individual furnaces and also as a check on the individual furnace operator.

Another important feature in the operation of an open hearth furnace is the control of the stack draft and the checker chamber temperature. There is no reason why a furnace could not be fitted with damper control in the same way that a boiler damper is controlled.

The reversing of the hot products of combustion at regular short intervals is very necessary, both from a fuel economy standpoint and also to increase the service life of the furnace checkers.

The logical control for the regular reversal of the gas and air would be a temperature control rather than a time control.

In addition to the various controls mentioned it is necessary to protect and preserve the lines of the furnace to the fullest extent during its campaign in order to obtain the greatest transfer of heat units from the fuel to the bath, the ports of the furnace being most important.

Those parts of the furnace which are subject to the greatest wear should be suitably protected in order that all parts of the furnace will age simultaneously as far as possible.

Wherever conditions warrant, waste heat boilers should be considered to recover from the waste gases heat for the purpose of raising steam for plant use and thereby return a credit to the open hearth operation. However, the real measure of the efficiency of any combustion system is the percentage of B.t.u. from the original fuel absorbed by the bath, rather than the amount of heat recovered for outside work.

The cause of many of the failures with controling devices has been the lack of interest on behalf of the operators in upkeep and repair of these devices.

The care of this apparatus belongs to a special service department in the industry and the need of it is being recognized by the leading steel plants.

The trade is constantly demanding steel of a better quality, which necessitates greater care in its manufacture for the purpose of meeting the changing specifications, and the margin of profit is so small that any device which tends to improve quality and economy in manufacture demands the consideration of the steel plant executive.

EARLY APPLICATION OF ELECTRIC HEATING IN THE IRON AND STEEL INDUSTRY

By D. M. PETTY*

THE first instance of the application of electric heating the writer knows of in the Iron and Steel Industry, was located in the Projectile Department of the Bethlehem Steel Company, at Bethlehem, Penna., in the year 1912.

It consisted of a rectangular tank filled with oil, in which a number of projectiles were placed and brought to a temperature of approximately 350° F. In the beginning this oil was heated by means of an oil flame, which played on the bottom of the tank. With this method of heating, a great deal of trouble was experienced owing to the fact, that the oil would vaporize and occasionally ignite on the surface due to the proximity of the oil flames. To overcome these difficulties an immersion heater was built, four units of which were placed around the sides of the tank, the resistor wire being in direct contact with the oil. The resistors were mounted in a wooden frame and so arranged that the top heating unit would be somewhat below the surface of the oil. The heating units were arranged in a horizontal position in the frame and consisted of a coil of resistor wire wound in a spiral about 1¼ inches in diameter. This was supported on porcelain insulators, which, in turn, were threaded on an iron rod. The two ends of each were fastened in the end pieces of the wooden frame; from 4 to 6 of these units were mounted in each frame. Normally each frame carried 48 amperes at 230 volts. four (4) frames were in use, the total capacity was 44 KW., which made a rather ambitious size of unit for the first instance of electric heating, as applied to production of iron and steel products. ....

The experience gained in this first application was later used in a number of similar applications, such as the melting of rosin and pitch.

The first attempt made to build an electrically-heated furnace in which the resistor was exposed to the air was a furnace for the purpose of heat treating, in which temperatures as high as 1700° F. were wanted. The first attempt to build a furnace of this kind was made early in the year 1914, and about the middle of that year, a successful furnace was placed in operation and remained in continuous use until the latter part of the year 1916. This furnace was also located in the Projectile Department of the Bethlehem Steel Company at Bethlehem, Penna.

This furnace was circular in construction, approximately four (4) feet deep and two (2) feet in diameter inside. The heating element consisted of heavy round resistor wire, which was supported by a non-oxidizing metallic frame, which fitted close against the side walls of the furnace and which was entirely self-supporting. It was built in this manner so that in case of a failure of the heating unit it could be lifted out of the furnace and a new one put in without any great loss of time; in fact, without waiting for the furnace to cool down to any appreciable extent. The resistor was carried on

*Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.

How To Reach Museum From Benjamin Franklin Hotel

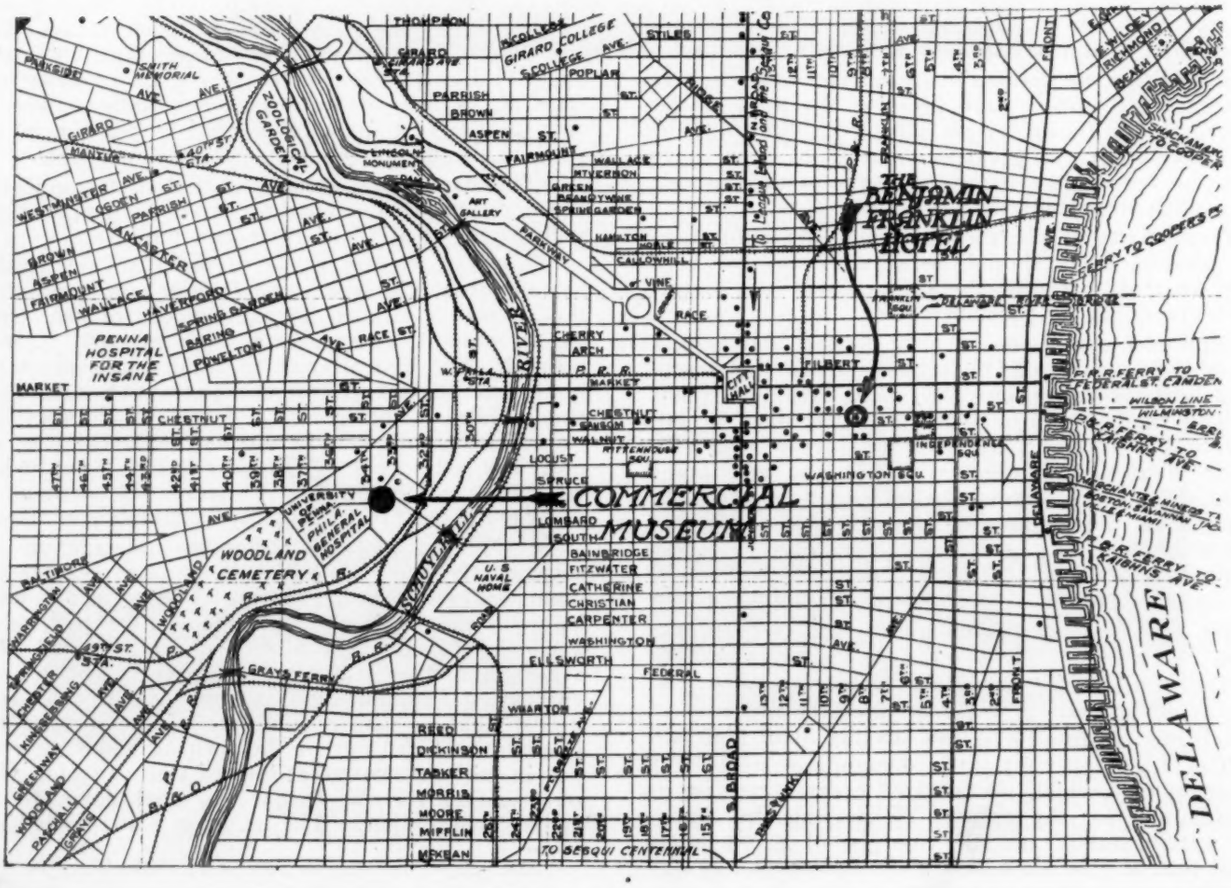
To reach Museum take any car southbound on Eighth or Tenth Street and transfer at South Street to Route 40 westbound.

An alternate route is by way of Route 13 on Walnut Street, one block from hotel, to Thirty-fourth Street. Museum is five minutes walk from this point.

You may also board westbound subway trains at Eighth Street Station of the Market Street Subway-Elevated, changing at Thirteenth Street to subway-surface routes 11, 34 or 37. These three lines pass the intersection at Woodland Avenue and Spruce Streets, about five minutes walk from the Museum.

The Walnut Street motor bus line Route D runs between Broad and Sansom Streets and Sixty-third and Walnut, and one stopping at Broad Street Hotels should find this route quite convenient.

Benjamin Franklin Hotel



heavy pieces of asbestos lumber, which was, in turn, fastened to the metallic frame. The resistor was made up in the form of a spiral, with one lead coming out of the bottom of the frame and the other from the top of the frame and leads were attached of sufficient length so that the connections were made at the top of the furnace. This layout made a very substantial furnace and did very good work in the heat treating of armor piercing projectiles. The resistor carried 125 amperes at 230 volts, or a total of 28 KW.

We gained a great deal of experience in designing and building this furnace in the matter of oxidization of steel, as in the first place the supporting frames were made of simple carbon steel. We found that this material oxidized very rapidly; in fact, was burned up long before the resistor wire had reached the end of its usefulness. We also found that, with the higher temperatures in use, it was necessary to limit the watts per square inch of resistor surface; the lower the watt density, the longer the life of the resistor element, it being necessary, of course, to increase the length of the wire whenever the cross-section was increased, in order to keep the KW. input to the furnace constant. The input to the furnace was regulated by means of exterior resistance, a number of switches being provided, so as to give four (4) heats in the furnace.

EXHIBITORS NOTES*

Booth No. 8

Square D Company
Detroit, Mich.

The Square D Company is planning an interesting and extensive display at the Exposition of Iron and Steel Electrical Engineers.

The Square D display will feature the new Convertible Power Panel, the novel construction of which has aroused great interest among electrical engineers whenever displayed.

The Voltage Tester, which requires no lamps, will also be featured at the exhibit, and demonstrations will be made to show how the device registers the voltage and indicates whether the current is AC or DC.

Another new device of the company, the motor starter for use with time limit protective cutouts, will occupy some space at the booth.

The Square D 80,000 series switches, quick make and quick break, with the new improved cross bar, will be an important part of the display.

A large number of Square D men will be on hand to insure all electrical engineers getting demonstrations and information about the Square D products promptly. The following representatives will be on hand: A. A. Schueler, E. L. Pittenger, E. W. Chapman, C. L. Hull, and J. J. Mitchell.

Booth No. 130

Chicago Fuse Manufacturing Company
Chicago, Illinois

A new design of "Union" renewable fuses of the knife-blade type will be a feature of the exhibit of the Chicago Fuse Mfg. Co., Chicago, at the Iron and Steel Exposition. This fuse is exceptionally simple in design and rugged in construction, and reduces maintenance costs by affording an unlimited number of blowouts as well as easy renewal.

Included in the exhibit there will be samples of the company's extensive line of renewable and non-renewable fuses, plug fuses, fuse blocks, switch boxes, outlet boxes and other electrical protecting materials and conduit fittings.

The exhibit is in charge of Mr. C. C. Lafferty, Cleveland District Manager of the Company.

Booth No. 109

National Electric Manufacturing Company
Pittsburgh, Pa.

An electric hammer, striking 3600 blows a minute, without motor or gears, is the SYNTRON Electric Hammer. It is rapidly gaining favor among industrial plants, contractors, and public service corporations. It has proven to be a remarkably efficient tool capable of driving star drills, chisels, stone points, bushing tools, etc., with great effectiveness. For instance, in drilling a hole in concrete, this hammer—the SYNTRON—can do in one minute what it would take a workman and a hand hammer at least 15 minutes to do. In other words, it will drill at the rate of 3 inches a minute.

The operating force used in the SYNTRON is a unique application of electro-magnets. The force is really magnetism alternately applied to the opposite ends of the piston. This piston is the only moving part. Confined within a bronze cylinder, it is caused to move back and forth, striking the inserted shank of the drill or chisel at one stroke and a recoil spring on the return stroke.

Alternating electric current, taken from the average light socket is all that is required to run it. In fact, the current consumption is about the same as for the domestic laundry iron. This current passes through a small control box, which is part of the SYNTRON outfit. Small electronic tubes in this control box so modify the ordinary alternating electric current, that it passes on to the hammer in such a way that it energizes, alternately, the separate windings around each end of the cylinder containing the piston. The result is that this piston is drawn back and forth with each electric pulsation or cycle. In 60 cycle current, then, the piston hits the inserted tool 60 blows per second or 3600 a minute.

This hammer, made in three sizes, is a portable one-man tool, that is easily carried about and operated by a single workman. A trigger switch gives him absolute control of the hammer at all times. The only care required is occasional oiling.

The time losses in doing all kinds of drilling and chipping in masonry are enormous. And we venture the guess that there is no one who will welcome SYNTRON more than the workman who has had the job of pounding a drill or a chisel hour after hour. Such work must be done in making all kinds of attachments to masonry, such as anchoring machinery, shafting, guards, in erecting signs, fire escapes, shelving conveyors, etc., in laying floor coverings and stair treads, in cutting openings for pipe lines, switch boxes, new doorways, etc.

The SYNTRON Electric Hammer is made by the National Electric Company, of Pittsburgh, Pa., and may be seen in operation in booth No. 109.

Booth No. 215

The American Electric Fusion Corporation
Chicago, Ill.

The American Electric Fusion Corporation, 2610-20 Diversey Avenue, Chicago, Ill., will exhibit in space No. 215, one of their latest types of motor driven automatic spot welders. This machine will be in constant operation during the exposition, and will illustrate the high speed at which effective spot welding can be conducted.

There will also be shown the new A. E. F. quick-change line contactor switch, which has been developed for large users of A. E. F. spot welders in the automobile field, where welders are employed in progressive assembly operations. This development has made high speed progressive assembly possible by eliminating shut downs for switch trimming or renewals.

*All writeups furnished by exhibitors.

From a comparatively unknown organization in 1920, occupying 1200 feet of floor space, this corporation has forged ahead until it is now one of the leaders in the industry, occupying its own modern plant with 15,000 feet of space on the northwest side in Chicago. Many of the large automotive plants have standardized on A. E. F. equipment, having found in it, features of design that make it particularly adaptable to their methods.

The A. E. F. Corporation also manufactures a complete line of seam welders, and is in a position to supply butt welders to order.

A publication entitled A. E. F. Welding Illustrated is published each month in the interest of better equipment and methods. This bulletin contains much that is informative in the way of theory and practice as well as examples of economies that can be effected through the use of electric welding equipment. Any readers who are not receiving this publication and desire it, need only to address the Corporation with a request for same, which will be promptly and gladly complied with.

Everyone interested in high speed automatic spot welding should not fail to see the A. E. F. exhibit in Philadelphia.

Booth No. 36

Standard Underground Cable Company
Pittsburgh, Pa.

The Standard Underground Cable Company is exhibiting in Space 36, samples of bare and insulated electric wires and cables for aerial service, lead covered and armored cables for underground and submarine service, and a line of cable terminals, junction boxes and jointing materials for both low and high voltage systems.

The company is represented by Mr. A. F. Hovey and Mr. S. F. Simkins, of Pittsburgh, and Mr. F. O. Hoyt, Mr. Max Rubenstein and Mr. H. K. Landon, of Philadelphia.

Booth Nos. 83-94

Allis-Chalmers Manufacturing Company
Milwaukee, Wis.

Allis-Chalmers Manufacturing Company will occupy spaces 83 and 94. The Company will feature its new Frog Leg Winding for direct current machines. A paper descriptive of this winding will be presented during the convention session. The Company will also show its new squirrel cage induction motor equipped with tapered roller bearings.

Booth Nos. 120-121

Keystone Lubricating Company
Philadelphia, Pa.

The Keystone Lubricating Company, Spaces Nos. 120 and 121, will demonstrate the Keystone Safety Lubricating System and its application to electric traveling cranes and other units of plant machinery.

This modern and expense saving system is meeting with wide and growing favor. To those who have not given the system careful consideration a cordial invitation is extended to visit the booths where information of vital interest may be obtained.

Many problems on the lubrication of various types of equipment are being solved and conditions, which for years have been a source of trouble and undue expense, are being corrected through the combination of the safe and positive application of the Keystone Safety Lubricator and the proper density of Keystone Grease. Some remarkable records of improved conditions and money savings have been made in the lubrication of foundry cranes, when it is considered that a lubricating device can be installed which will earn a complete return of the investment cost within a period of from 4 to 6 months.

The conclusion must be reached that plant executives generally will quickly take steps to eliminate time-worn and costly methods after they have become familiar with this modern system and fully appreciate the facts concerning its performance. Visitors are invited to ask for specific details concerning actual money savings recorded in the foundries of some of America's largest industries.

An exposition of the large and comprehensive line of Keystone Grease Products will be given, including the popular Keystone No. 6 Light Liquid Grease for the lubrication of ring type electric motor bearings. Close attention should be given and information asked concerning the performance of this lubricant and records of savings in maintenance expense, due to its non-creeping qualities, which prevents oil soaked windings and premature deterioration of mica segments.

Booth Nos. 132-141

Otis Elevator Company
New York, N. Y.

Otis Elevator Company will exhibit in Booths 141 and 132 their latest type of full automatic Furnace Hoist Control, with operating switch, and their new type automatic Stop Motion Switch. This Stop Motion Switch is of new design and is arranged to replace the old Stop Motion Switch on existing Hoists, and has the following new features:

The operating cams are accessible for adjustment without disturbing any part of the Switch. Individual contacts can be readily removed and the shaft carrying the operating cams can be removed without disturbing the rest of the Switch. The Switch is also provided with a totally enclosed easily removable cover.

Further, the Otis Elevator Company will show samples of its steel castings, including the large hollow spiders for Gearless Traction elevator machines, pot castings of special steel to withstand high temperatures used in hardening processes. There will be many smaller castings used by automobile concerns and tool manufacturers, together with a complete set of test bars of all the different kinds of steel which they make.

Booth No. 71

M. H. Detrick Company
Pittsburgh, Pa.

At the Iron and Steel Exposition, our exhibit will consist of a model showing the design of a Detrick Flat Suspended Arch used generally in connection with chain grate stokers burning coke breeze, anthracite and bituminous coal.

The model clearly shows how each row of center slotted tile is supported by durable castings and how the castings, in turn, are supported from structural steel members, giving the arch a simplicity and flexibility that are of prime importance in the design of flat suspended arches. With slight modifications, the model shows the details of construction used in industrial furnaces of all kinds, as continuous heating furnaces, soaking pit covers, annealing ovens, etc.

We will also have on exhibit several interesting blue prints showing the application of the Detrick Flat Suspended Arch to various combinations of boilers and stokers, and also to many different types of industrial furnaces, such as mentioned above.

Booth Nos. 156-157-164-165-188-189-204-205

Westinghouse Electric and Manufacturing Company
East Pittsburgh, Pa.

The Westinghouse Exhibit at the Annual Iron and Steel Convention, will consist of the following:

Standard type "SK" Westinghouse Direct current motor for general mill service. This motor will have a section cut away so that the entire details of construction and insulation may be shown.

A standard Westinghouse "SK" motor will be rigidly coupled to a mill type "MC" motor and the motors will be electrically connected for a load back test to show the commutation features of the "SK" motor.

In connection with this exhibit, the company will also demonstrate Westinghouse Steel Mill magnetic control and the new design type "DI" brake.

Small static condenser unit for power factor correction will be shown in actual operation. The static condensers will be connected to an inductive load, and a switchboard panel will be arranged to show the power factor correction obtained when the static condenser units are connected in the circuit.

Westinghouse Type "CL" carbon circuit breakers of various capacities, will be exhibited, and arrangements will be made to operate these breakers.

A Westinghouse 200 ampere portable arc welding unit will be on exhibition and an arc welder will be available to demonstrate this outfit.

Booth Nos. 114-135

The Electric Controller & Mfg. Co.
Cleveland, O.

Our Exhibit will feature the new No. 1 size Youngstown Safety Limit Stop which has been developed to take care of small and medium capacity cranes where space for mounting is restricted. The No. 1 Youngstown Stop will take care of motors up to and including 30 HP, 230 volt and 550 volt, it uses a single operating weight, quick break and switching mechanism and contacts are provided with powerful magnetic blowouts.

We will also feature the new Type Z0 push button operated oil immersed across-the-line starting switch for A.C. motors up to and including 10 HP.

We will also show a 100 HP, 2300 volt EC&M oil immersed automatic Compensator.

Also we will have a working exhibit of a full magnetic A.C. control and master switch operating in connection with a reversing slip ring motor.

Booth No. 43

The Roller-Smith Company
New York, N. Y.

In the circuit breaker line the following recently developed and marketed types will be shown:

Interlocked Trip Type. In this type of breaker the poles are closed independently but open simultaneously. This breaker is recommended for motor and feeder circuits and displaces knife switches and fuses.

Free Handle Type. The Free Handle breaker is so arranged that it cannot be closed or held closed on an overload, even though the operator's hand is on the handle. In other words it is Non-Closable on Overload.

Shock Proof Type. Circuit breakers are frequently wanted for operation under certain conditions where there is excessive vibration or where the breakers are subjected to mechanical shocks of such intensity as to cause undesired opening with possible serious results. The Shock Proof type covers this requirement.

Dead-Front Type. These breakers are so arranged that they are mounted on the baek of the panel or switchboard with only the operating handle and indicating target on the front. The Dead-Front breaker was put on the market to take care of the increasing tendency towards the use of Dead-Front switchboards.

In addition there will be shown some of the many other styles of circuit breakers which form a part of the Roller-Smith Company's extensive line.

In the instrument line we will feature the GS line of portables, which are moderate priced, but accurate and rugged instruments for general service testing. The exhibit will include the GSD line for direct current comprising ammeters and milli-ammeters; voltmeters and millivoltmeters and volt-ammeters. The GSA line for alternating current includes ammeters and milli-ammeters, voltmeters, volt-ammeters, single and polyphase wattmeters, frequency meters and power factor meters.

There will be shown also representative types of our extensive line of A.C. and D.C. switchboard instruments including the Triplex ammeter.

Booth No. 22

The United States Graphite Company
Saginaw, Mich.

The United States Graphite Company will have a complete display of the various styles, types and grades of USG carbon, graphite, and metal Motor and Generator Brushes they manufacture with special emphasis laid on those for use in steel mills. This exhibition will also include other carbon products as well as lubricating graphite and other Mexican Graphite products.

Mr. J. J. Edmiston, Philadelphia District Office Manager, will be in charge of the booth and will be assisted by Messrs. F. B. Godard and R. J. Edmiston of Pittsburgh, Mr. R. A. Corrigan of Chicago, and Mr. C. W. Adams, Manufacturing Engineer, of Saginaw, Michigan.

Booth No. 106

The Ohio Electric and Controller Company
Cleveland, Ohio

At Booth No. 106, The Ohio Electric and Controller Company has but one thought to impress upon your mind and that is that we specialize upon lifting magnets and their control.

To accomplish this end we show parts illustrating the complete internal structure of Ohio Magnets, and especially the insulation and terminal details.

When a magnet circuit is opened a heavy kick voltage is generated which, if not absorbed, endangers the controller, the magnet coil and lamps or motors connected to the same circuit.

The Ohio Magnet Controller takes sure care of this condition; it provides limited reserse current for quick drop yet is small, compact and substantial. The controller is shown operated by current from an Ohio Motor Generator.

It is frequently necessary to connect and disconnect magnets, temporary motor drives such as welders, roll heaters, etc., and a great deal of time is consumed twisting wires and taping, and furthermore, such work requires the service of an electrician.

To overcome this expense and loss of time, we have developed the Ohio Armored Weatherproof Connector which is exhibited in single, double and three-pole form.

The Connector is described by its name. It has butt contact capable of carrying 150 amperes on continuous, and 300 amperes on intermittent work. The contacts wipe 45 degrees in making or breaking and anyone can make or break connection without tools or tape.

Paul Diver, Harry Saunders, Roy Wertz or Frank Jessop will be very glad to see you at Booth No. 106 for The Ohio Electric and Controller Company.

Booth No. 210

Heppenstall Forge and Knife Company
Pittsburgh, Pa.

Heppenstall Forge and Knife Company of Pittsburgh, will have in their Exhibit, a display of Rolling Mill Forgings and a pair of Shear Knives for hot cutting.

Among the forgings will be a Housing Screw finished machined with a forged prolongation showing the manner of taking test pieces for determining whether the screw has had the proper heat treatment. This Housing Screw will be made from Vanadium Steel which has been quenched and drawn.

There will also be a heat treated Tinning Roll of a scleroscopic hardness of about 45. This roll is a high grade standard Tinning Roll.

In connection with the Shear Knife display, there will be on Exhibit some knives which have given exceptional service in shearing blooms and billets.

Booth No. 117

Rollway Bearing Company, Inc.
Syracuse, N. Y.

We will exhibit at the Iron and Steel Electrical Exposition the following articles:

"ROLLWAY" Maximum Double Width Bearings.
"ROLLWAY" Aligning Bearings.
"ROLLWAY" High Speed Bearings.
Thrust Bearings for Worm Gears.
Crane Hook Thrust Bearings.

In addition, we will exhibit a complete line of our "ROLLWAY" housings (patents on which have been applied for) also our commercial type of bearings which we

designate as our Wide Series. We purpose, in addition, having samples of bearings and housings for one or two of the newest and heaviest applications which have been made in the steel industry in the past year.

Booth No. 47.

Monitor Controller Company
Baltimore, Md.

The Monitor Controller Company will feature in this exhibit their new Edgewound Resistor, which differs radically from the types of resistor generally in use. This entirely new form of resistor consists of a nickel copper ribbon wound on edge and then mounted on a steel reinforced support, the whole being designed to make a resistor which is not damaged by shock or vibration, maintains the same resistance at all temperatures and as much smaller and lighter than is possible when cast materials are used. Forms especially adapted for steel mill use will be shown.

In addition Monitor will exhibit various types of Automatic Controllers.

Booth No. 224

Mutual Foundry and Machine Company
Atlanta, Ga.

It is our purpose in conjunction with the Gehnrich Indirect Heat Oven Company and the John C. Dolph Company to furnish a very complete composite demonstration of the most modern and up-to-date equipment for the electrical maintenance departments of Industrial Plants, as well as an actual demonstration by experts of the efficient use of this equipment.

The equipment manufactured by the Mutual Foundry and Machine Company will consist of the complete line of Browning Coil Making Apparatus, showing the latest improved models of this equipment. The Browning Loop and Field Winder is one of the most useful and powerful machines of its kind on the market. A number of mechanical improvements have been incorporated in the construction of this machine during the past year, and it now provides a very delicate and powerful control, as well as additional adjustable features in connection with the Winding bar. This machine has the capacity, equipped with 1½ h.p motor, to handle any number of wires under heavy tension, that may be required to make up the most difficult types of coils ordinarily met with in repair shop practice.

The new type of Browning Coil Spreader will also show a number of improvements in mechanical construction, which not only make it easier and quicker of operation, but also considerably more attractive in general appearance. This machine is the most accurate and rapid of its type now available on the market, for the reproduction of motor coils in exactly the same shape they occupy in a motor.

The third item which we manufacture in connection with the previous two machines is the Browning Combination Reel Rack and Tension Device. This machine incorporates a very unique tension principal, using polished bronze pressure plates to secure the desired tension on magnet wire of any description. Actual pressure of as much as 100 pounds applied through springs on these pressure plates produce satisfactory results without damaging the cotton or other type of covering on magnet wire.

In connection with the Browning Equipment, we will have in service a motor driven Coil Taping Machine, and also a high grade Insulation Cutting Shear.

This exhibit will be in direct charge of our Factory Expert, Mr. W. H. Harris, and in connection with our Eastern Agents, Porter & Ross, Inc., of New York. Both Mr. Harris and Mr. Ross are thoroughly conversant with modern repair shop practice, and will be prepared to demonstrate the manufacture of any type of coil which can be most satisfactorily produced with this equipment. We will also be interested in demonstration of the Gehnrich Baking Ovens and Dolphs Insulation Varnishes, as these products are handled by our Company and our Agents in connection with the sale of repair shop equipment which is manufactured by us.

Booth No. 112

The Pyle-National Company
Chicago, Illinois

At the National Convention of the Iron and Steel Engineers at Philadelphia, the Pyle-National Company will exhibit their ney Type 2375-AG Floodlight, which is fitted with a 23 in. guaranteed life glass reflector. The body of this projector is made of cast aluminum and sheet aluminum alloy, all pins and latches are of brass or bronze.

They will also exhibit floodlights in the 10 in., 12 in., and 14 in. size, made of cast aluminum alloy.

Turbo-generators ranging in capacity from ½ to 7½ K.W. will also be shown, as well as a complete line of locomotive wiring devices, and headlight cases.

Messrs. T. P. McGinnis and W. H. Haas will represent the Company.

Booth No. 115

Martindale Electric Company
Cleveland, Ohio

Martindale Electric Company, Cleveland, Ohio, will exhibit in Booth 115 a line of Motor Maintenance Equipment.

IMPERIAL Commutator Stones, made of an artificial abrasive were placed on the market 5 years ago, October 1, 1920. They are now in use by more than 3,600 companies in this country, and are well known throughout the world. One of their customers is Tata Iron and Steel Company in India, who began using IMPERIAL Stones in March, 1921. An order was received from them last July amounting to $1,699.20. The IMPERIAL Stones cut freely, do not drag copper and can be depended on to quickly remove ridges, high bars, flat spots and other commutator defects except eccentricity, which cannot be fully removed with hand stones.

IMPERIAL Commutator Grinding Tool. This tool, when bolted on the brush arms of a motor or generator, forms a rigid support for the lathe type IMPERIAL Commutator Stones, and is recommended where commutators are badly eccentric.

IMPERIAL Undercutter for slotting commutators is driven by a ¼ H.P. motor through a flexible shaft. This machine is supplied with either "V" shaped high speed steel milling cutters to cut "V" shaped slots or with the ordinary slotting saws to cut square bottom slots.

HANDY Commutator Slotting Files are also supplied for cutting "V" shaped slots and are recommended for use in plants where there is not sufficient undercutting to warrant the purchase of a motor driven outfit.

IMPERIAL Commutator Cement is ready mixed, easy to apply and is rapidly replacing the old form of separate powder and liquid which had to be mixed when wanted.

COMMULAC is a di-electric liquid for painting commutator slots to prevent short circuits from oil, moisture or dirt. It forms a high resistance film over the mica in the slot, does not peel away from the edges of the slot and does not soften under ordinary sparking of the brushes.

PREMIER Handy Blow-er Clean can be used either as a portable blower or suction cleaner, and the change can be made in a few seconds. It has hundreds of cleaning uses in addition to blowing dust out of electrical equipment.

All of the above articles are illustrated in their advertisement in this issue and will be exhibited and demonstrated at Philadelphia.

Other articles to be exhibited include IMPERIAL Commutator Cleaner, MARTINDALE No. 7 and No. 13 motor driven commutator slotters, and IMPERIAL Armature Coil Slot Cleaning Equipment.

Booth No. 222

The John C. Dolph Company
Philadelphia, Pa.

The John C. Dolph Company, Philadelphia, Pa., is planning to have a Model Repair Shop at the coming Iron and Steel Electrical Show, to be held in Philadelphia.

Through the courtesy of the Mutual Foundry and Machine Company, the builders of the Browning Coil Winding and Forming Apparatus, and the Gehnrich Indirect Heat Oven Company, we intend to carry the complete

operation of winding and insulating a number of good size armatures.

Men of authority on coil making and forming, also on oven construction and baking problems, together with an Insulating Varnish Engineer, will be on hand at booths Nos. 222, 223 and 224, to advise you.

No matter how trivial your insulation problems are, be sure and stop at the Dolph display and talk over the subject with men who have given a life study to the above mentioned problems.

The use of the Air Brush for cleaning coils and applying air drying finishing varnishes will no doubt prove of interest. Electric Lacquer will be applied to coils and then be subjected to interesting tests.

The Chinalak treated motor running in the acid bath will no doubt interest you. We shall be very glad to tell you how the motor was treated in order to withstand the severe operating conditions.

Booth No. 140

Stackpole Carbon Company
St. Mary's, Pa.

This exhibit represents the evolution of a Stackpole carbon brush and shows every form of raw material that goes into its composition as well as the product in various stages of its manufacture. It also includes testing apparatus used to control and insure absolute uniformity.

On one table will be placed a number of labeled containers with raw materials. Directly in front of these containers will be molded blocks of carbon in the green or unbaked state, in the baked form and some that have passed through an electric furnace. The latter form is commonly known as graphitized carbon. On the same table will be shown modern types of shunt connections. Among these will be the well known bolt and nut that is so popular on brushes where extremely low electrical resistance between brush and shunt is necessary. Each type will be shown in cross section also.

One table will be equipped with a carbon block resistance tester such as is used on a production basis for inspection. Next to this will be placed an apparatus for testing the millivolt drop between the brush and shunt. This also is in use by our inspection department and is a good example of improvements that make possible large production with accurate inspection.

Another table will have a scleroscope for determining relative hardnesses of carbons, a crushing strength tester and a contact drop and coefficient of friction machine.

This exhibit should be especially interesting to those who have so often wondered at the mysteries and dark secrets involved in carbon brush manufacture and its technical control.

Descriptive pamphlets and catalog will be available.

Booth No. 50

Crocker-Wheeler Company
Philadelphia, Pa.

The Crocker-Wheeler Company expects to have on display at the A. I. S. E. E. Exhibit in September, the following apparatus:

1, size 20-P, 2 HP, 1700-rpm, 60-cycle, 2 phase, 220-volt, squirrel cage motor with railbase and pulley, illustrating a new line of polyphase induction motors, built in four frame sizes and covering a range in horsepower from ½ to 2-HP.

These machines are ball bearing and incorporate a number of refinements in electrical and mechanical design, which add to the reliability and fine appearance of the machines.

1, size HF, 3-HP, 1150-rpm, 230-volt, shunt wound, direct current motor, representative of a new line of F motors to replace the form L motor, now so favorably known. These machines will have ball bearings and be arranged for conduit wiring and will cover a range in horsepower of from ½ to 7½-HP at standard induction motor speeds.

Illustrating the next larger line of direct current motors covering a range in horsepower of from 5 to 50-HP, we will exhibit a:

Size DH, 30-HP, 1700-rpm, 230-volt, shunt wound, ball bearing interpole type motor. This line will shortly replace the form J and JA machines, which have been built for a number of years and will enable the Company to better take care of the demand for adjustable speed direct current motors within the range of horsepowers mentioned. This line will fill the gap between the F motors and the present larger H machines.

As illustrating their line of direct current mill motors, they will have on exhibit an AW, 230-volt, series wound motor, which is the smallest of their line. Motor will be provided with tapered shaft and roller bearings. The insulation is made up entirely of mica and asbestos and the same extra rugged mechanical construction is employed as on the larger motors of this line.

The Company will exhibit two sizes of their auto transformer type remote control starters, which combine a large number of desirable features, all of which are not found in any other starter.

Booth No. 216

The Electric Journal
Pittsburgh, Pa.

The Electric Journal is proud to be a real part of the activities of the electrical engineering of the iron and steel industries. It is gratified with the wonderful progress the Association of Iron and Steel Electrical Engineers has made, and appreciates the earnest work of its members that has brought about such valuable practical results.

Concurrent with the Association's twenty-one years of growth, The Electric Journal has been of continuous service to the Association, as well as to every Electrical Engineer in the Iron and Steel and allied industries, with articles and data that help solve the technical problems of their every day work.

For nine years The Electric Journal has featured the Association's Convention with a special color section in its advertising pages that gives manufacturers an opportunity to express their interest and co-operation and familiarize these Electrical Engineers with their equipiment.

Each year this color section has kept pace with the growth of the Association's activities. The Electric Journal plans to continue to serve the Association in every possible way, feeling that it is of real value to both Engineers and the Manufacturers.

The Electric Journal's September issue will have an entire section advertising pages of representative firms whose broad spirit of co-operation takes this practical form of wishing the Association continued success and a greater growth and influence.

Philadelphia can justly be proud of having this Convention September 14 to 18, 1925.

Booth No. 199

McGraw-Hill Company, Inc.
New York, N. Y.

The McGraw-Hill Company will exhibit three of its publications which are of particular interest to electrical, mechanical and combustion engineers in the iron and steel industry.

"INDUSTRIAL ENGINEER" is devoted to the problems of those men in mills and factories who are responsible for the installation, operation and maintenance of electrical and associated mechanical equipment. Its readers include the principal engineers in the iron and steel field.

"ELECTRICAL WORLD" is the leading engineering and business publication of the electrical industry. It is concerned with the fundamentals of electrical engineering **as a profession,** the production, distribution and application of electrical energy **as a service;** and the broad problems of production, distribution and application of electrical equipment **as a business.**

"POWER" has for more than 40 years been a leading and guiding influence among power plant men. Edited by the largest editorial staff in its field, it has its place wherever power is generated. That the publication is closely allied with the iron and steel industry is evidenced by the

fact that of its 27,500 readers, 3,600 are in metal working plants.

The McGraw-Hill Company also publishes 12 other business, engineering, industrial and radio publications.

In attendance at the Exposition will be a number of executives of the McGraw-Hill Company, editors, and business and advertising men.

Booth No. 133

The Thompson Electric Company
Cleveland, Ohio

The Thompson Electric Company, Cleveland, Ohio, will exhibit their line of Safety Lowering Switches, or Disconnecting Hangers, enabling overhead lamps to be lowered to the ground for cleaning and renewals.

The greatest problem in lamp maintenance is accessibility, and the Thompson Electric Company have been engaged for a number of years in perfecting a type of lowering equipment which will enable the overhead lamps to be mounted in such manner that the maintenance work can be done with ease and safety, and the lamps made to yield their maximum results continuously instead of for just a brief period while they are new, clean and sparkling.

In some places the Thompson Hanger-Switch is recognized as a necessity. Under other conditions it may be regarded more as a convenience; but in the industries a convenience usually facilitates production and promotes safety—two of the most important factors in efficiency, or the successful development of a business. It is difficult, therefore, to draw a line between an industrial convenience and a necessity. Many thousands of Thompson Hanger-Switches are helping overhead lamps to make good, by enabling the maintenance work to be done with ease and safety down on the ground. They help to eliminate both climbing hazards and electrical hazards.

The Thompson Electriic Company have been working upon the theory that there must be four essential factors involved in the success of a Hanger-Switch for industrial use: it must be simple in design and substantial in construction; it must function successfully, and it must be inexpensive. The Thompson Hanger-Switch is undergoing a continuous process of development and improvements with these four factors in mind, and its success is attested by the many thousands that are continually going into service.

Booth No. 131

Corliss Carbon Company
Bradford, Pa.

The chief interest in the exhibit of the Corliss Carbon Company, Bradford, Pa., will be centered around a device for testing the resistance of carbon brushes. This will be used primarily to show the unique feature of a new graphite grade which has a resistance across the thickness of seven times the longitudinal resistance.

The function of this grade is to restrain the short circuit currents caused by the brush spanning two or more commutator bars and at the same time to offer as little resistance as possible to the load current passing in or out of the brush. The restraint of the short circuit currents will, of course, decrease and often eliminate sparking and the resultant burning and blackening of the commutator. This improved commutation makes abrasive action unnecessary in brushes for flush mica commutators; there is no destructive sparking to burn the copper away from the mica.

Other elements of the exhibit will be brushes of various styles, and the raw materials and different steps in the manufacture of brushes.

Booth Nos. 145-152-153-168-169-176-177-192-193-200-201

General Electric Company
Schenectady, N. Y.

The General Electric Company expects to exhibit the following: Steel mill type motor with solenoid operated brake. Mill type controller with three point master switch and unit box resistor. This is the new type control recently placed on the market. Magnetic switch with cast iron cover for throwing motor across the line. Hand operated motor switches. New DC general purpose motors. New crane motor. DC drum controller. General purpose induction motor. Truck type panel with solenoid operated AC circuit breaker. 2000 ampere, 15000 volt oil circuit breaker.

The General Electric Company will occupy Booths 152, 153, 168, 169, 176, 177, 192, 193, 200 and 201.

Booth No. 194

The Philadelphia Grease Mfg. Co.
Philadelphia, Pa.

"The Philadelphia Grease Manufacturing Company, Main Office and Works at Philadelphia, Pa., will exhibit in booth No. 194, and will have on display samples of Philadelphia Grease, the Quality Lubricant, which is manufactured in several densities suitable for all classes of lubrication. They will also display different types of grease cups.

The Booth will be in charge of Mr. Horace A. Smith, President of the Company, who will be pleased to welcome all visitors and explain the different densities and their various uses."

Booth Nos. 25-32

The Morgan Engineering Company
Alliance, Ohio

Will exhibit several models of our special machines, consisting of the following:

A four-girder type Ladle Crane with large and small trolleys.
A screw type Ingot Stripper.
A low Stiff Leg Type Soaking Pit Crane.
A low type Open Hearth Floor Charging Machine.
A Morgan Crane Controller.
A Morgan-Wackerly type Limit Stop.

They will have their Morgan-Wackerly type Limit Stop connected up with a 10 H. P. motor operated by a Morgan Controller. By this hookup we will be able to give a practical demonstration of the stop and show the functioning of same through its entire range of operation.

Booths Nos. 22 and 23

Pittsburgh Transformer Company
Pittsburgh, Pa.

Among the things to be seen at Pittsburgh Transformer Company's booth will be an exact model of a 3-Phase Self-Cooled Power Transformer. This is a reproduction to scale of a 15,000 KVA Polyphase Transformer and shows clearly the tank construction and the method of attaching the new Film Type Radiators to the transformer tank.

Models of Single-Phase Self-Cooled Power Transformers equipped with cores and coils will be seen in operation. These will show the tank construction for the large single phase power transformers, as well as the design and construction of the core and coil.

An improved Tap Changer Switch will also be exhibited, together with a Film Type Radiator (actual size). Cross sections of this radiator will also be shown to illustrate its construction.

Many of the Operating Engineers visiting this convention will be interested in seeing our 3-Phase and Single-Phase distribution transformers, and in our booth will be displayed one of each of these types of distribution transformers.

As has been the custom at each previous convention, Pittsburgh Stogies will be free at the Pittsburgh Transformer Company's booth.

Booth No. 213

The Economy Electric Products Company
Cleveland, Ohio

The Economy Electric Products Co. will exhibit at the Iron and Steel Exposixtion, the lightest, heavy duty, 250 ampere portable Arc Welder built.

The Welder weighs, complete, 550 pounds, and is mounted on 30" Ford Wheels, and is easily moved about by one man.

This Welder has been designed to meet the requirements in the mill yard, for welding of copper tuyers, Manganese steel, high carbon steel and general welding of all kinds.

This machine requires about 25% less current to do a given amount of work than any Welder made.

The high efficiency thus made possible is the chief reason for the small size and weight and the great portability. An almost equally important element in the economy of weight is the novel patented magnetic circuit used in the field. Instead of a pole piece bolted to a yoke, as in the usual construction, each pole is made of three separate or divided parts, and these parts are separated and held in place by non-magnetic metal.

Booth Nos. 166-167-178-179

Condit Electrical Mfg. Co.
South Boston, Mass.

The Condit Electrical Mfg. Co. has the following material arranged for exhibition:

A Type F-99, heavy duty, truck type, oil circuit breaker. This breaker is of all-steel construction and equipped with double tanks. Exceptionally rugged construction is used throughout, and the energy absorption principle is employed in the design of this breaker. The purpose of this type of construction is to absorb mechanical shocks incident to the rupturing of heavy short circuits on high power systems, and to reduce to a minimum the hazard which usually follows the throwing of hot oil and gases emitted on heavy short circuits.

A Truck Type Switchboard complete with housing is also exhibited. This switchboard is designed for 15,000 volt service equipped with type D17B, double tank, oil circuit breakers. The housing and the truck are of exceptionally heavy reinforced steel construction. The truck is provided with adequate mechanical interlocks. Automatic shutters prevent accidental contact with current carrying parts when the truck is removed.

Other exhibits include a Condit "Standard" Semaphore, which permits the loading of transformers by temperature, and Condit Type N-4 Oil Motor Starter for the control and protection of small motors..

Booth No. 48

Allen-Bradley Company
Milwaukee, Wis.

Squirrel cage motors are not likely to be injured by heavy starting currents due to the absence of commutators or other complex parts of limited current capacity. However, large starting currents may seriously affect alternating current power lines and generating apparatus, especially if synchronous equipments are operated from the same circuit. In many cases the motor must be accelerated slowly to avoid damage to the driven machinery.

Compensators can hardly be expected to accomplish a gradual start of a squirrel cage motor, since two distinct current rushes will take place. One, when motor is connected to the reduced voltage and one when motor is conncted to full voltage. The latter current rush can be many times the first one, depending on the phase relation of motor and line when connecting to full voltage. The Allen-Bradley graphite compression disc type starter provides an absolute gradual acceleration, eliminating all strains on the driven machine and reduces line disturbances to a minimum. There are absolutely no current peaks.

In addition to the standard line of manual and automatic squirrel cage motor starters, the Allen-Bradley Company will have also their new line of enclosed direct current manual and automatic starters, semi-automatic reversing crane controllers, and dynamic lowering controller, on display.

Booth No. 45

Electric Storage Battery Co.
Philadelphia, Pa.

The Electric Storage Battery Company, makers of Exide Batteries, the world's largest manufacturers of storage batteries for every purpose have an interesting exhibit at booth No. 45.

The display features a number of oil paintings dramatizing Exide Batteries in the Iron and Steel Industry.

There are also batteries cut away to show construction of the Exide-Ironclad type as well as the Hycap or flat plate type.

Displays of the Ironclad cells for industrial truck and tractor service and also for use in mine locomotives are shown and may be examined by those interested. One of the Giant Exide-Ironclad cells for use in industrial storage battery locomotives is also shown. This is the largest battery of its kind, being almost as large as those used in submarines.

An added attraction at the Exide booth is the display of the complete line of improved radio batteries now being made by this company.

The six-volt Exide "A" Battery with its new monoblock composition construction presents to the radio world a battery whose appearance will be in keeping with the furnishings of any room. There are also two low voltage "A" batteries for use with small tubes.

Two new "B" batteries of the glass cell type, a 24-volt unit and a 48-volt unit, each having a 6,000 milliampere hour capacity are shown. In the Exide radio group is included a chemical rectifier for charging "B" batteries and low voltage "A" batteries.

Competent men will be present in the booth to explain the many applications of the storage battery in the Iron and Steel and allied industries.

Booth No. 108

National Carbon Company, Inc.,
Carbon Sales Division, Cleveland, O.

The National Carbon Company will be located at Booth 108, and will exhibit a complete line of carbon, graphite and metal graphite brushes for direct current motors, generators and rotary converters.

Experienced Engineers will be at our booth at all times during the convention with the one aim to help solve any problems that the various Electrical Engineers may have pertaining to brush applications.

There will be on exhibit, carbon contacts and carbon specialties of all descriptions, as well as welding carbons, blocks and paste for use for welding in the steel industry.

It will be worth while for all interested in the Electrical Departments of the steel mills to stop at our booth and receive a copy of our brush bulletins, describing in detail, troubles and their remedies. These bulletins are based on actual experience and are really worth while having.

Booth No. 220

The Homestead Valve Mfg. Company
West Homestead, Pa.

The Homestead Valve Mfg. Company will exhibit a very complete line of all the products of their manufacture, which will be of interest in the iron, steel and affiliated industrial plants.

The Homestead Quarter Turn Valve in the straightway, 3-way and 4-way patterns, and the Hovalco Blowoff Valve are well known throughout the industry and have paved the way for the interest recently shown in the Homestead Protected Seat Hydraulic Operating Valve and the Homestead Protected Seat Globe Valve. Each of these products have features of design and construction which have resulted in exceptional service in many parts of the industry.

The Homestead Protected Seat Hydraulic Operating Valve, however, will be of especial interest to all users of hydraulic power and machinery.

The sectional cut shows the general construction of the 3-Way Valve and the small cut at the side shows a detail of the seating elements.

In the opening and closing action of the valve a protecting sleeve telescopes around the neck of the seat bushing and almost cuts off the entire flow of fluid previous to the actual contact of the seating elements. In this manner the protecting sleeve allows the seating members to make contact with practically no water flowing across them and therefore eliminates any cutting or wire drawing due to the high velocity of the water coming in direct contact with the valve elements just as they are separating or coming together. The protecting sleeve also tends to keep sand, grit, sediment, etc., from crossing the surfaces of the seating elements while the valve is closing and in this way prevents these elements from being scored.

In addition to the protecting sleeve, which is, of course, the main feature of the valve, the construction is such as to permit renewal of the vital elements without taking the valve from the pipe line.

A cam is suitably designed to make for ease of operation and prevent water hammer. Side thrust on the valve stems is eliminated by means of floating guide blocks interposed between the end of the valve stem, the cam itself. Means are provided for adjusting by a screw and lock nut.

The Homestead Protected Seat Operating Valve is not an experimental proposition. It has been thoroughly tried during the last four years and found to be of sound design. It is for this reason that the Homestead Protected Seat Operating Valve will last for more than 19 months on the same manifold, doing the same work, where other types of valves require replacement of parts every three days to one week.

Booths 113, 136, 137 and 160.

Electric Service Supplies Co.,
Philadelphia, Pa.

The Electric Service Supplies Co., of Philadelphia, New York and Chicago, will exhibit their broad lines of electrical equipment in Spaces 113, 136, 137 and 160. Representatives of this company in attendance at the exhibit will include Messrs. Barry, Nordfeldt, Towle, Schmidt, Kopprasch and Spraggon.

A comprehensive exhibit of this company's industrial electrical material will include Keystone Contact Rail Material, Segur Coil Winding Tools, Protected Rail Bonds, Peerless Armature Shop Tools, Keystone Expulsion Arresters, Franklin Porcelain Insulators, Beam and Strain Clamps, Keystone Pantagraph Collectors, Armature Baking Ovens, Keystone Pinion Pullers, Golden Glow Floodlights and Headlights, Keystone Turbo-Generators, Keystone Lamp Guards and other miscellaneous and closely allied material.

This company has its main office and plant at Seventeenth and Cambria streets, Philadelphia, and extends a cordial invitation to all who may desire to visit this plant.

Booth 76

The Sharples Specialty Company,
Philadelphia, Pa.

The Sharples Specialty Company (Centrifugal Engineers) of Philadelphia, will exhibit a standard commercial lubricating oil purifier, motor driven; a cross-section of this commercial machine, and a laboratory size centrifuge.

The purification of any used lubricating oil by Super Centrifugal force has unusual advantages. The Super Centrifuge removes dirt, carbon water emulsions, sludges and abrasive materials that accumulate in an oil during service. Its action is rapid and positive, and its use requires none of the additional oil supply or settling tanks, necessary in filter systems. The Super Centrifuge is the simplest oil purifier available; there is no complicated internal mechanism to be handled or cleaned when impurities are to be removed from it.

The Sharples Booth No. 76 is prepared to demonstrate these recognized advantages of Super Centrifugal Force. At the request of any visitor a typical lubricating oil will be purified or, if any member cares to bring a one-gallon sample of oil used in his plant, a demonstration will be made on such a sample.

In addition, the facilities of the Sharples experimental and testing laboratories in Philadelphia will be at the disposal of any member who may wish to make use of this unusual opportunity for scientific investigation of their particular problems.

Booth No. 211

Schweitzer & Conrad, Inc.,
Chicago, Ill.

Schweitzer & Conrad, Inc., of Chicago, who have been consistent exhibitors at the annual convention during the past few years, are showing an attractive display of their indoor and outdoor High Voltage Protective and Switching Equipment.

This includes samples of the S&C Fuse up to 132,000 volts, with various forms of Fuse Mountings, Type DP Fuse Cutout, Type E Ejector Cutout, Type H Lightning Arrester, Voltage Detectors, Disconnecting Switches, Choke Coils, Bus Supports, Fuse Tongs, etc.

A feature which is attracting a great deal of attention is the S&C Pantograph Air Break Switch. This is an ingenious application of the pantograph action, which results in a high speed positive motion of the switch blade, permitting it to enter a fully housed contact clip with one simple direct movement.

An improved Safety Disconnect, which is of particular interest to Iron and Steel Engineers, is also shown. This Safety Disconnect permits opening a fully loaded circuit without danger to the operator or damage to the switch from arcing between blade and contact. An S&C Fuse is mounted on an auxiliary insulated blade in parallel with the main blade. When the main blade with its quick break attachment is pulled, the current is diverted through the Fuse, which blows and interrupts the circuit without arcing.

S&C Representatives in attendance include Messrs. P. T. Bradley, of Philadelphia; H. N. Muller and H. E. Ransford of Pittsburgh; J. L. Scanlon, of Buffalo, and A. D. Fishel, of Cleveland.

Booth Nos. 26-31

The Cutler-Hammer Mfg. Co.,
Electric Controlling Devices
Milwaukee, Wis.

The Cutler-Hammer Mfg. Company exhibit will consist of an Inductive Time Limit Controller, using the 300 ampere size mill type contactors, together with a two-speed mill type master controller and necessary cast iron grid resistance connected to a 25 H.P. Crocker-Wheeler series shunt mill type motor, provided with a Type M Brake mechanism, with hand wheel for load adjustment. This equipment will be connected to a source of D.C. power, so that it can be operated showing the features of the acceleration. This controller accelerates the motor in a predetermined time, depending upon the adjustment of the special inductive time limit accelerating contactors in connection with a choke coil or transformer mounted on the rear of the control panel. The accelerating contactors are provided with a holding out coil, which opposes the action of the closing coil. This holding out coil is connected to a coil on the choke coil, which is, in turn, magnetically coupled with the magnetic circuit of the choke coil and electrical connections so made that the inherent time lag of this choke coil are used to provide a delay in closing of the accelerating contactor. In other words, the electrical inertia of a highly inductive magnetic circuit are used to obtain a time interval to control the acceleration of the motor. This time interval is adjustable by adjusting a magnetic air gap on the accelerating contactor.

There will also be a mill controller built up of the 600 ampere size contactors. There will also be on exhibit a new design of compound reversible drum controllers providing armature starting and field regulating, which has been specially designed for machine tool and steel mill service. The need feature of this drum controller is the use of readily renewable units mounted directly on the field finger assembly board. The rear of the booth will contain display panels with photographs of typical mill installations of magnetic controllers, lifting magnets, magnetic clutches, magnetic weights, etc.

Booth No. 154

Economy Fuse and Manufacturing Co.,
Chicago, U. S. A.

As usual, the Economy Fuse and Manufacturing Compaany will participate as one of the exhibitors, Booth No. 154. We have always been earnest supporters of the Association of Iron and Steel Electrical Engineers, and have availed ourselves of a booth for the display of our products at every Convention of the Association since its inception.

We shall have on display, as usual, a full line of Economy Renewable Fuses, together with the famous "Drop-out" renewal link, the only type of renewal element which provides proper protection for an electric circuit.

We shall also have on display, our line of Clearsite Plug Fuses (non-renewable), which plug fuses, by the way, contain our "Drop-out" link. The fuse always operates in the restricted area, immediately under the clear mica window in the top of the plug, thus furnishing evidence at all times, whether the fuse plug has blown or not. This is a very distinctive feature, and one that should be of interest to all who have many times, probably, had to locate which fuse plug had actually blown.

We shall also have on display a few non-renewable cartridge fuses, which will be of interest to those whose fuse replacements are not large, and who may not be interested in Economy Renewable Fuses.

Our booth will be in charge of R. L. Heilman, District Sales Manager of our Philadelphia office, and W. L. DeCoursey, District Sales Manager of our Pittsburgh office, and we shall be pleased to greet you in Philadelphia, at our booth.

Booth No. 64

Celite Products Company
Pittsburgh, Pa.

The Celite Products Company are manufacturers of the various forms of high temperature heat insulation marketed uider the trade names of Sil-O-Cel. All of these products are produced from an excepitonally high grade deposit of diatomaceous earth which forms a part of the holdings of the manufacturing company in California. This diatomaceous earth is known commercially as Celite to distinguish it from the many other forms of diatomaceous earth which are marketed under various other trade names, most of which do not have the same properties possessed by Celite, due to the presence of foreign matters such as clay, sand or other inorganic compounds which may be classed as impurities and undesirable constituents. Celite, due to its freeness from such foreign matter, is exceptionally porous and light in weight, and being diatomaceous earth is composed of practically pure silica in an amorphus form.

Due to the physical composition and structure of the material and the dead air cells of microscopic size which are distributed uniformly throughout the mass, Celite is a most efficient form of insulation, suitable for both low and high temperatures. All Sil-O-Cel products produced from Celite have the same characteristic properties, as regards their efficiency as heat insulators.

Brick cut from the natural Celite rock, known as Sil-O-Cel Natural Brick, are suitable for exposure to temperatures up to 1600 deg. F. and another brick known as Sil-O-Cel C-22, which is a dry pressed calcined product, is suitable for exposure to temperatures up to 2200 deg. F. By comparison, Sil-O-Cel is about one-twelfth as conductive of heat as fire brick inch for inch.

Sil-O-Cel Powder is another form of the natural Celite in powdered form for use where a powdered form of insulation is desirable.

Sil-O-Cel C-3 is a calcined granular product which may be used in the loose form or which may be bonded with Portland Cement to form a strong, durable monolithic form of insulation.

Almost without exception Sil-O-Cel in its various forms has been used in the steel industry in the last few years for insulation of heated equipment. This includes bottoms, side walls and arches of open hearth regenerator chambers and flues, settings of waste heat and direct fired boilers, soaking pits and regenerators, sheet and pair furnaces and other types of heating furnaces, blast furnace stoves, hot blast mains and bustle pipes, metal mixers, gas producers, etc.

The Celite Products Company has offices which are in charge of competent engineers in the principal cities of the United States.

Booth Nos. 190-191-202-203

The Reliance Electric & Engineering Company,
Cleveland, O.

The following will give you brief information concerning our exhibit at the Iron & Steel Exposition.

We are to exhibit:

Type AA Reliance Induction Motors, ball bearing, roller bearing and sleeve bearing types.

Type T Heavy Duty Reliance Motors for direct current, ball bearing, roller bearing and sleeve bearing types. A special water-tight and dust-tight design.

First Type T Motor shipped, with armature interchanged with present design, indicating that no changes affecting interchangeability have been made in this line for 10 years.

Booth Nos. 19-38

The Fuller Lehigh Company,
Fullerton, Pa.

The Fuller Lehigh Company of Fullerton, Pa., will exhibit at the Iron and Steel Exposition a model of Fuller Horizontal Burner, a model of Fuller Vertical Burner, a Fuller Single Screw Feeder, a working model of Fuller-Kinyon Pump and Conveying System, a model of Randolph Waste Heat Dryer (vertical), a Fuller-Kinyon Automatic Switching Valve.

In addition to the above they will have large photographs showing various equipment and installations made by their company, together with many blue prints of work being done.

They will also exhibit a model of the Fuller-Lehigh Pulverizer Mill.

Booth Nos. 118-119

V. V. Fittings Company,
Philadelphia.

The V. V. Fittings Company, having their main office and factory in Philadelphia, will exhibit a complete line of their V. V. reversible and interchangeable conduit fittings in various sizes, among which there are some new and interesting developments.

V. V. Safety Switches will be exhibited and demonstrated in the many types and sizes made by this company, both in sheet steel and cast iron weatherproof enclosures, ranging from 30 to 1500 ampere sizes.

This line of Safety Switches is built up on the policy of "Build the switch for the condition," hence there are switches for the hardest and most varied service.

There will be a competent staff in attendance.

Booth Nos. 217-218

The Packard Electric Company,
Warren, O.

The Packard Electric Company of Warren, O., will have on exhibit at the forthcoming convention of the Assn iation of Iron and Steel Electrical Engineers representative types of their complete line of distribution transformers. These transformers, which are all of core type construction, permit a maximum amount of the coil surface and the active portion of the transformer to be exposed to the cooling action of the oil, thus insuring rapid dissipation of heat and allowing the transformer to run cool under severe load conditions.

The cores of Packard Transformers are cut from the highest grade of transformer sheet obtainable and are built up with extreme care in such a manner as to make a strong mechanical structure as well as embodying the best electrical characteristics.

Transformer tanks are of copper bearing sheet steel, with reinforced base, gray cast iron covers and in the larger sizes a gridded cast iron base.

Component parts of Packard Power Transformers will be on display as well as a photographic display of representative Packard Power Transformer installation, transformer elements and factory facilities.

There will also be exhibited a Packard tap changer (patented), which is said to be meeting with a great deal of favorable comments where the necessity exists for making changes in tap connections.

There will be Packard Weatherproof Metering Transformers on display. These units with potential and current elements combined in the same oil filled tank, have many novel features. They are coming more and more into prominence where high voltage metering is required.

An ample supply of literature describing the Packard line will be on hand and engineers will be in attendance

to supply any specific information desired in connection with Packard Transformers.

Booth No. 21

The Trumbull Electric Manufacturing Company, Plainville, Conn.

The Trumbull Electric Manufacturing Company's exhibit will include complete lines of Industrial Switches, Motor Starting Switches, and Panel Boards.

Special attention will be given to Type "A" Switches, made in 30 to 1200 Amperes, Quick Make and Quick Break, 250, 440 and 550 Volts.

We wish to call particular attention to our 600-V Switches, equipped with snuf-arcs, because they recently have passed most satisfactory tests when operated under load on Direct Current.

These tests have been passed on to the Underwriters and we expect approval on our 30-200-Ampere Switches for use on Direct Current as well as Alternating Current.

Such approval will be unique in Switches of Knife Switch construction.

Several types of Motor Starting Switches will be exhibited, including:

1. A Tumbler Switch for fraction horse power motors, as well as for use on lighting circuits.

2. A two position motor starting switch, R. M. Type, which shunts the fuses in starting position.

3. A switch with Time Limit Protective Cutouts.

4. A switch with overload relays and under voltage release, with guaranteed protection against damage from single phase operation.

A new type of Standardized Unit Panelboards will also be exhibited.

Booth No. 223

Gehnrich Indirect Heat Oven Co., Inc., Long Island City, N. Y.

This company will exhibit at the Iron and Steel Exhibition in Philadelphia an electrically heated industrial oven. In conjunction with the John C. Dolph Company, of Newark, N. J., armatures will be baked in this oven and other demonstrations will be made for processes of interest.

The oven will be of the well-known Gehnrich panel type construction with the most improved principles of heat distribution and ventilation.

Booth No. 58

Republic Flow Meters Co., Chicago, Ill.

The Republic Flow Meters Company will exhibit along with the Electrically Operated Flow Meter for Steam, Gas and Water (of which there are hundreds installed in over 130 Steel Mills), a self-contained motor-driven CO2 Recorder, Indicating and Recording Pyrometers, and Draft and Pressure Indicators. These instruments are presented to iron and steel men as accurate methods for the solution of their problems in boiler control, temperature measurement, and steam, water and gas distribution.

Probably the larger number of those who will be present at the exhibit are familiar with the advantages of the Republic Flow Meter—flexibility in adaptation to steel plant conditions—high accuracy, and small upkeep costs.

Many steel plants are completely equipped with steam flow meters on the boilers for efficient steam production; and steam, water and gas distribution meters with the reading instruments centrally located. One steel plant engineer sums up the advantages as follows:

(1) They give information for correct accounting.

(2) Give valuable knowledge of load demands and variations.

(3) A method for bringing about immense savings in steam, water and gas.

(4) Develops a keen interest in department operation.

(5) An absolute check on the amounts used.

The new CO2 Recorder is a unique development; its self-contained feature is a distinct advantage.

Republic Pyrometers with their wide charts and scales and high resistance, making for greater accuracy, will be of special interest to those men in charge of blast furnace operation, forging and heat treating. Don't fail to spend a few minutes while you are at the Exhibit at Booth 58.

Booth No. 18

Robinson Ventilating Company, Pittsburgh, Pa.

Robinson Ventilating Company, builders and designers of fans for all uses for over a period of 35 years, are exhibiting a striking display at the Iron and Steel Exposition. This company specializes in mine fans, forced and induced draft fans, and pressure blowers. Their products are very well known wherever ventilating problems are in evidence and the engineering skill embodied in the construction of Robinson models has created widespread approval. In their line is included the well-known Man Kooler Fan, which has so conclusively demonstrated its efficiency for increasing the output of men working where heat conditions are very severe. Robinson Wall Type Exhaust Fans and Type I Centrifugal, for heating and ventilating purposes, are equally well known.

The Engineering personnel of this company is of the very highest calibre and puts them in an admirable position to build special fans for special uses. Wherever especially bothersome ventilating problems are to be solved, Robinson engineers have submitted practical, economical solutions. Over a period of years, they have built up a reputation for efficiency and economy which is not surpassed by any similar group in the industry.

The company is represented at the Iron and Steel Exposition, held at the Commercial Museum, Philadelphia, September 14th-18th. A complete exhibition of all types of fans of their manufacture will be on display and it will be worth your while to make a thorough examination of these products. Iron and steel engineers will note that the compact and rugged construction of Robinson Fans is but one of the many points of superiority which go to make up their efficiency. Engineers will be in attendance at the booth to answer questions and explain the relative merits of the products.

Booth No. 207

Tool Steel Gear and Pinion Co., Cincinnati, Ohio.

The Tool Steel Gear and Pinion Co., Cincinnati, will have on exhibit samples of products they are furnishing for the steel mill—cast and cut tooth, spur and bevel gears, gearing for cranes, cables, hoist, etc., cut tooth mill pinions, spindles and coupling boxes, leveller rolls and similar products. All of these are made in hardened material, which greatly outlasts the ordinary grades. They will also have samples to illustrate the method of hardening.

Booth No. 110

The Erie Malleable Iron Company, Erie, Pa.

The Erie Malleable Iron Company, of Erie, Pa., announces a new type of threadless conduit fitting, tradenamed Kondu-Box, for which great economy of installation is claimed. A complete line of these fittings, both round and oblong, are in production.

The distinctive merit of the Kondu-Box fitting is the fact that it grips the conduit securely by means of a tapered bushing, thus eliminating the cost of thread cutting and the labor of screwing the conduit into place.

A case-hardened bushing, having tapered threads for a lock nut and a tapered base, is the basic feature of Kondu-Box design. This bushing takes a parallel grip on the conduit, due to its tapered thread being balanced by a slight taper on the interior of the body in which it seats; the grip is reinforced, and a perfect running ground secured at the same time, by means of sharp ridges or rings on the interior of the bushing. These ridges are forced through the enamel and cut into the conduit when the

lock nut is tightened. A slot in the bushing is so arranged as to have a band brake action which serves as an effectual lock against loosening by vibration and requires a minimum amount of effort to grip the conduit properly.

Simplicity and economy of conduit construction are claimed for Kondu-Boxes, because the fittings slip into position on the line without necessity of screwing up the conduit. Thus, any sort of bond may be made in the conduit and any desired type of fitting inserted at any point without recourse to unions or running thread. The exactness with which Kondu-Box joints are made, as compared with the variations encountered with threaded joints, makes it practicable to cut conduit to drawing dimensions when these fittings are used.

The fact that the Kondu-Box is made of certified malleable iron gives it strength and immunity from breakage, as proven by most gruelling tests in independent laboratories. It is, in practice, virtually unbreakable, and its grip stands more than 50 per cent greater tensile strain than does the approved threaded conduit fittings.

The manufacturer points to many other advantages and refinements in this fitting. For example, an ingenious but very practical method of assembly makes it impossible to remove the screws from the metal Kondu-Box covers, while the porcelain covers have fibre washers forced into the countersunk screw holes, which not only retain thes crews in place, but provide an adequate cushion under the screw heads to prevent the cracking of covers from excessive tightening.

The Kondu-Box line, the manufacturer states, is complete for all requirements. Not only is there a complete assortment of round and square boxes for various sizes of pipe, but also there are the necessary threadless couplings, adapter bushings for standard steel knock-out boxes, adapters for connections to flexible conductors, etc. These enable the installer to complete a threadless job with no other tools than a wrench, a hack-saw and a reamer, and with a saving in labor which is claimed to exceed 50 per cent of the labor required for an equal installation of threaded fittings under similar conditions.

The Erie Malleable Iron ompany will be represented at Space 110 in the Iron and Steel Exposition, Philadelphia, by Mr. R. P. Dunmire, General Sales Manager, and other officers of the company. Sample Kondu-Boxes are being distributed at this booth, together with booklets, wall charts and other descriptive matter. Those who do not attend the exposition are invited to write for additional illustrated data to the Erie Malleable Iron Company, Erie, Penna.

Booth Nos. 196-197

Edwin L. Wiegand Company,
422 First Ave., Pittsburgh, Pa.

The exhibit in booths Nos. 196 and 197, which this company will have at the Exposition will be of great interest to the Iron and Steel Engineers. The entire line of "Chromalox" Electric Strip Heaters will be shown, as well as many interesting applications.

A complete roll heater, as put out by Freyn Engineering Co., of Chicago, in which "Chromalox" Strips are used, will be of particular interest to Sheet Mill Engineers.

This Company manufactures heating units exclusively, of the enclosed type, with the idea of meeting every requirement for electric heat. Literature dscriptive of the complete line will be available, as well as many samples.

The exhibit will be in charge of Mr. Ernest N. Calhoun, Sales Manager, together with Messrs. H. E. Trent and L. P. Hynes.

Booth No. 116.

Mutual Electric and Machine Company
Detroit, Mich.

We will have on display our Safety Switch Display Board on which will be mounted various types of "BULL DOG" Type "A" Safety Switches for Severe Service Duty.

These bear Underwriters' Classification "A" for Fire and Safety, and are equipped with full Safety Interlocks so that door of Cabinet cannot be opened until Switch is first thrown "OFF" and Switch cannot then be thrown "ON" until door is first closed. Blades and Fuses are "dead" when Cabinet is open. All operating Switches are Quick-Make and Quick-Break.

We will also display a few of our "JUNIOR" Enclosed Switches, designed for lighter duty and where their operation by qualified persons only, obviate the necessity for Safety Interlocks, effecting a considerable saving in price. The "JUNIOR" Line is also Quick-Make and Quick-Break.

Item 2. An illuminated Photographic Display of "BULL DOG" Safety Type Dead Front Switchboards for Industrial Plants. These Switchboards embody the following factors—SAFETY, SIMPLICITY, DURABILITY, POSITIVE OPERATION, ACCESSIBILITY and ECONOMICAL INSTALLATION.

Our representatives at the Convention will probably be the following: Mr. S. B. Frank of Cleveland; Mr. L. H. Hind of Pittsburgh; Mr. J. V. Flood of Philadelphia.

Booth Nos. 20-37.

The Baker R & L Company,
Cleveland, Ohio.

At the Philadelphia Exhibition, we plan on exhibiting three models, the Baker Hy-Lift Truck, the Baker Electric Tractor and the Baker Locomotive Type Crane, which is illustrated in the photograph. These machines, as well as other Baker models, have the ruggedness and strength which is necessary for steel mill operation and there are countless handling operations in the industry where money can be saved from the payroll by these versatile machines.

The Locomotive Crane has a 70-inch wheel base, 50-inch platform and 12 ft. boom, and a special hook, which was devised for this purpose.

The Baker exhibit will be in operation in Commercial Museum several days in advance of the opening of the show, in order to assist in placing some of the heavier exhibits.

Booth Nos. 17-40.

The Norma-Hoffmann Bearings Corporation,
Stamford, Conn.

At the Iron & Steel Exposition the Norma-Hoffmann Bearings Corporation, Stamford, Conn., will exhibit in booths Nos. 40 and 17, its complete ilne of Norma open and closed type ball bearings, Hoffmann ball, roller and thrust bearing, and also Hoffmann rollers and roller gauages.

In addition, there will be on display an operating model illustrating the precision of large, heavy duty roller bearings and also a moving exhibit to show the features of self-aligning roller bearings. Another interesting model which will be shown has been designed to illustrate the free-running qualities of small high precision ball bearings.

In order to show various methods of mounting, a few electric motors will be used, these being sectioned at the end plates so as to permit of a view of the bearings and surrounding parts. Both ball and roller bearing equipped motors will be shown.

One of the features of the exhibit will be drawings and phtographs illustrating methods by which sleeve type mill motors may be changed over to accommodate Hoffmann roller bearings at comparatively small cost. These will cover all makes and sizes of mill type motors.

The exhibit will be in charge of Mr. D. E. Batesole and H. J. Ritter.

Booth No. 60

Tinius Olsen Testing Machine Company
Philadelphia, Pa.

Our exhibit is assembled with the idea of demonstrating standard methods of testing, as well as the latest type of special testing machines required in developing varying properties possessed by steels. This exhibit will have in operation a 20,000 lbs. capacity Olsen Universal Testing Machine upon which will be demonstrated the latest type Olsen Special Extensometer. Instruments will be on exhibit for determining the behavior of material when tested, among which will be Strain Gauges and Extensometers of the dial type which indicate accurately changes in length

and by means of which stress strain diagrams showing the behavior of the material can be accurately and quickly obtained.

There will also be on exhibit a 120 ft. lbs. Olsen Combined Cantilever type Impact and Impact Tension Testing Machine, which is used in determining the shock resistance of steels. The exhibit will also include the Olsen Hydraulic Brinell Hardness Testing Machine complete with Microscope, as well as the Herbert Pendulum Hardness Tester and Latest type hand operated Ductility Testing Machine. This latter machine is used in classifying sheets as to their drawing properties. There will also be in operation a Massachusetts Institute of Technology Folding Endurance Paper Testing Machine.

The machines described above will be on exhibit and attendants will be present during the exhibit who are prepared to explain the operation of any testing equipment manufactured by the Tinius Olsen Testing Machine Company.

Booth Nos. 17-40.

Norma-Hoffman Bearing Corporation
Long Island City, N. Y.

At the Iron and Steel Exposition we will exhibit in our booth, numbers 40 and 17, our complete line of Norma open and closed type ball bearings, Hoffmann ball, roller and thrust bearings, and also Hoffmann rollers and roller gauges.

In addition there will be on display an operating model illustrating the precision of large heavy duty roller bearings and also a moving exhibit to show the features of self-aligning roller bearings. Another interesting model, which will be shown, has been designed to illustrate the free running qualities of small high precision ball bearings.

In order to show various methods of mounting, a few electric motors will be used, these being sectioned at the end plates so as to permit of a view of the bearings and surrounding parts. Both ball and roller bearing equipped motors will be shown.

One of the features of the exhibit will be drawings and photographs illustrating methods by which sleeve type mill motors may be changed over to accommodate Hoffmann roller bearings at comparatively small cost. These will cover all makes and sizes of mill type motors.

The exhibit will be in charge of Mr. D. E. Batesole and Mr. H. J. Ritter.

Booth No. 51

The Okonite Company
Passaic, New Jersey

The Okonite Company will exhibit at Booth 51, samples of Okonite rubber covered wire and cables; also Varnished cambric cable; samples of Okonite Callender impregnated paper cables; Okocord; Okonite Rubber Tape, and Manson, Dundee A and Dundee B Friction Tapes.

Booth Nos. 195-198

Appleton Electric Company
Chicago, Ill.

Mr. C. O. Anthony, Philadelphia representative, Mr. G. H. Conn, Cleveland representative and Mr. E. G. K. Anderson, Chief Engineer, will represent the Appleton Electric Company. Mr. A. S. Merrill, General Sales Manager and Mr. F. H. Merrill, Vice President, will also be in attendance.

There will be exhibited a diversified line of UNILETS —Steel Conduit Fittings—made of Open Hearth Drawing Steel.

The REELITE—an automatic take-up reel for electrical conductors will also be shown. The REELITE solves one of the troublesome problems of industry—that of electrical current for portable machines, portable lights and motor-driven tools.

There are many situations where bare current conducting rails are not practical from either a safety or an operating standpoint. On the other hand, loose cables dragged over the floor through oils and under the wheels of trucks always require repairs, with consequent expense and loss of operating time.

The REELITE keeps the cable neatly coiled in a steel container, free from kinks, breaks or tangles. It pays the cable out as needed, and then retrieves it when the job is finished. The action is entirely automatic—like that of a window shade.

MOGUL REELITES are made to take any length of cable of any gauge or number of conductors, and can be built into any kind of machine requiring electric power.

COMMITTEE— GENERAL ARRANGEMENTS

TWENTIETH ANNUAL CONVENTION

GEO. H. SCHAEFFER, General Chairman

HEADQUARTERS—THE FOYER, MEZZANINE FLOOR, BENJAMIN FRANKLIN HOTEL.

Registration and Bureau of Information Headquarters

F. H. Kitteridge, General Chairman
Headquarters—The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

RECEPTION COMMITTEE

J. R. Penman, Chairman
Headquarters—The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

ENTERTAINMENT COMMITTEE

Monday Evening—Informal Dance

P. T. Vanderwaart, Chairman
Headquarters—The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

Thursday Evening—Dinner Dance

F. O. Schnure, Chairman
Headquarters—The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

Iron and Steel Exposition Committee Philadelphia Commercial Museum

Headquarters—Main Canopy Booth
Center of Hall—John R. Doyle in charge.

NATIONAL EXECUTIVE COMMITTEE HEADQUARTERS

The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

INVITATION COMMITTEE

W. S. Hall, Chairman
Headquarters—The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

PHILADELPHIA EXECUTIVE COMMITTEE

L. O. Morrow, Secretary
Headquarters—The Foyer, Mezzanine Floor, Benjamin Franklin Hotel.

Twentieth Annual Convention and Iron and Steel Exposition

Philadelphia Commercial Museum, Philadelphia, Pa.

SEPTEMBER 14th to 19th, 1925

Association of Iron and Steel Electrical Engineers.

Electrical, Combustion, Safety Divisions

TECHNICAL SESSIONS

MONDAY, SEPTEMBER 14th, 1925, 12:30 Noon—Benjamin Franklin Hotel, Chrystal Ball Room.

SAFETY DIVISION—L. H. Burnett, General Chairman; C. L. Baker, Vice Chairman

The first session of the Convention will be devoted to the Safety Division. Starting with a Luncheon at 12:30 the program will be continued until completed.

CHRYSTAL BALL ROOM

1:30 P. M.—Introduction—A. C. Cummins, President A. I. & S. E. E.

Remarks—L. H. Burnett, Assistant to President Carnegie Steel Co., Pittsburgh, Pa.

Remarks—Henry A. Renninger, Assistant to President Lehigh Portland Cement Company, Allentown, Pa.

"How the Electrical Engineer and the Safety Engineer Can Be Mutually Helpful," By John A. Oartel, Chief of Safety Bureau, Carnegie Steel Co., Pittsburgh, Pa.

TUESDAY, SEPTEMBER 15th, 1925—Philadelphia Commercial Museum.

D. M. Petty, Chairman. **F. W. Cramer, Secretary.**

9:30 A. M.—"The Selection and Maintenance of Oil Circuit Breakers," By George A. Burnham, Condit Electrical Mfg. Co., Boston, Mass.

11:00 A. M.—"The Selection and Maintenance of Oil Circuit Breakers," By M. J. Wohlgemuth, Switchboard Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. and E. K. Reed, Circuit Breaker Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

12:00 Noon—Lunch—Cafeteria, Philadelphia Commercial Museum.

1:00 P. M.—Discussion of Papers—"The Selection and Maintenance of Oil Circuit Breakers."

WEDNESDAY, SEPTEMBER 16th, 1925—Philadelphia Commercial Museum.

C. S. Proudfoot, Chairman. **F. W. Cramer, Secretary.**

9:30 A. M.—"Direct Current Armature Windings for Multipolar Generators and Motors," "Frog Leg Windings," By W. A. Powell and G. M. Albrecht, Engineering Dept., Allis Chalmers Mfg. Co., Milwaukee, Wisc.

THURSDAY, SEPTEMBER 17th, 1925—Philadelphia Commercial Museum.

George H. Schaeffer, Chairman. **H. C. Seibert, Secretary.**

Joint Session: Electrical and Combustion Sections

9:30 A. M.—"Electric Heat Treating Furnace Applications," By E. A. Hurme, Manager, Steel Mill Division, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

"Electric Melting Furnaces," By J. A. Seede, Industrial Engineer, General Electric Co., Schenectady, N. Y.

Report of Electrically Heated Soaking Pit in operation at the Donner Steel Company.

FRIDAY, SEPTEMBER 18th, 1925—Philadelphia Commercial Museum.

R. S. Shoemaker, Chairman. **F. W. Cramer, Secretary.**

9:30 A. M.—"Auxiliaries and Auxiliary Drives for Steam Electric Generating Stations," By A. L. Penniman, Jr., and F. W. Quarles, Consolidated Gas, Electric Light and Power Co. of Baltimore, Baltimore, Md.

W. P. Chandler, Chairman. **G. R. McDermott, Secretary.**

11:00 A. M.—"Extending the Heat Cycle in Boiler Operation by the Use of Preheated Air for Combustion," By J. G. Worker, Vice President, American Engineering Co., Philadelphia, Pa.

ENTERTAINMENT

MONDAY EVENING, SEPTEMBER 14th—Chrystal Ball Room, Benjamin Franklin Hotel

P. T. Vanderwaart, Chairman.

Informal Dance—9:00 P. M.—Visitors Welcome.

THURSDAY EVENING, SEPTEMBER 17th, 1925—Chrystal Ball Room, Benjamin Franklin Hotel

F. O. Schnure, Chairman.

Dinner Dance—6:30 P. M.—Visitors Welcome.

Motion Pictures—Lecture Room, Philadelphia Commercial Museum

Tuesday, Wednesday, Thursday, Friday—2:30 P. M. to 4:30 P. M.—7:30 P. M. to 9:30 P. M., Except Thursday.

Queen of the Waves—Wizardry of Wireless—World of Paper—The Consolation Club—White Coal—Romance of Rails and Power.

Special Feature—Wednesday Evening At 7:30, the Diesel Type Engine, Illustrated With Motion Pictures. Lecture By George A. Richardson, Bethlehem Steel Co., Bethlehem, Pa.

INDEX TO ADVERTISERS

A

Alliance Machine Company 441
Allis Chalmers Mfg. Company 422
American Heat Economy Bureau 487
American Pressed Steel Company 462
Appleton Electric Company 471

B

Baker R. & L. Company 463
Bartlett Hayward Company 438
Benjamin Electric Mfg. Company 481
Bussmann Manufacturing Company 427

C

Calebaugh Self Lub. Carbon Co. 469
Chicago Fuse Mfg. Company Insert
Cleveland Crane & Engr. Company 418
Condit Electrical Mfg. Company 408-409
Corliss Carbon Company 429
Crocker Wheeler Company 464
Crouse Hinds Company 434
Cutler Hammer Mfg. Company 474
Cutter Electrical & Mfg. Co. 483—Cover 3

D

DeLaval Steam Turbine Company 430
Delta Star Electric Company 462
M. H. Detrick Company 443
Doubleday Hill Electric Company 432
Duquesne Light Company 476

E

Economy Electric Products Company 470
Economy Fuse & Mfg. Company 447
Electric Controller & Mfg. Co. Cover 1
Electrical Development & Machine Co. 482
Electrical Engineering & Mfg. Co. 419
Electric Power Equipment Corp. 472
Electric Service Supplies Company 452
Erie Malleable Iron Company Insert

F

The Fafnir Bearing Company 484
Farrel Foundry & Machine Company 456
Fawcus Machine Company 469

G

Gehnrich Indirect Heat Oven Company 454
General Electric Company Insert—Cover 4

H

Harnischfeger Corporation 436
The Hayward Company 478
Ludwig Hommel Company 470
Hyatt Roller Bearing Company 449

I

Iron City Electric Company 465

J

Johns Manville, Incorporated 425

K

Keystone Lubricating Company 437

L

Le Carbone Brush Company 448
George T. Ladd Company 433

M

Martindale Electric Company 460
Moloney Electric Company 467
Monitor Controller Company 428
Morgan Construction Company 465
Morgan Engineering Company 457
Morganite Brush Company 420

N

National Carbon Company 423
New Departure Manufacturing Company 442
Nichols Lintern Company Insert
Norma Hoffman Bearing Corp. 486
R. D. Nuttall Company 479
Ohio Electric & Controller Company 477

O

Okonite Company 450
Otis Elevator Company 485
J. H. Overpeck Company 466

P

Packard Electric Company 488
Pittsburgh Electric Furnace Corp. 451
Pittsburgh Transformer Company 473
Pyle National Company 455

R

Reliance Electric & Engr. Company 458
Republic Flow Meters Company 461
Roller Smith Company 480
Rollway Bearing Company 444
Rowan Controller Company 421
Rumsey Electric Company 471

S

Shepard Electric Crane & Hoist Co. 426
SKF Industries, Incorporated 453
F. L. Smidth & Company 459
Smith & Serrell 468
Stackpole Carbon Company 431
Standard Underground Cable Company 412
Strom Ball Bearing Mfg. Company 439

T

Thomas Flexible Coupling Company 440
Thompson Electric Company 466
Timken Roller Bearing Company 435-475
Tinius Olsen Testing Machine Co. 445
Tool Steel Gear and Pinion Company 463
Trumbull Electric Manufacturing Co. 446

U

United States Graphite Company 467

V

V. V. Fittings Company 424

W

Western Electric Company 410–411
Westinghouse Electric & Mfg. Co. Cover 2—407-13-14-15-16-17

Y

York Insulated Wire Works of G. E. Co. 464

*Direct Current Armature Windings For Multi-Polor Generators and Motors—Frogleg Windings**

By W. H. POWELL† and G. M. ALBRECHT‡

Introduction:

THIS paper is intended to review the development of the art in the winding of drum type direct current armatures, and then to describe some recent improvements which have been made in the balancing of the circuits whereby commutation has been improved, capacity increased for a given speed or speed increased for a given capacity, speed regulation of motors, or voltage regulation of generators, adjusted by a slight shifting of brushes without impairing commutation. There will also be described some tests made under abnormal conditions to show the effect of the balanced windings when the magnetic circuits have been unbalanced.

The paper is divided into three parts, the first being elementary with a brief review of the development of the art and a description of the new winding, the second is a discussion of the results obtained, and the third is a technical description of how the connections are made in order to obtain balanced circuits on multiplex windings.

Part I

In the modern drum type direct current armature with coils embedded in slots in the core, there are two types of windings now in use, viz., the series or two circuit winding, also known as the "wave winding" and the parallel or multiple circuit winding known as the "lap winding."

The series winding consists of a coil of one or more turns whose active conductors are placed in slots which are approximately one pole pitch apart and whose ends are soldered to commutator bars which are approximately two pole pitches apart.

If the circuits were traced through a four pole armature, a few coils of which are shown in Fig. 1, starting at any commutator bar, as for example one located under a positive brush on the upper half of commutator, one circuit would go clothwise with the coil sides located in slots under the leading tip of the north and south poles on the right side of machine. The other end of coil would be fastened to commutator bar under positive brush on lower side of commutator to which is also fastened the beginning of another coil. The circuit would continue clockwise, with coil sides located in slots under the leading tip of the north and south poles on the left side of the machine. The other end of coil would go to commutator bar located behind the starting point. Tracing a similar circuit in the counter clockwise direction, there will be found coil sides under each of the four poles. The end of second coil would go to commutator bar adjacent to starting point. On this four pole armature, there are two coils in series between any two adjacent commutator bars with coil sides symmetrically located under both north and south poles. If the circuits are traced by continuing in clockwise direction to one of the negative brushes, it will be found that the circuit has included one-half the total number of coils. The coil sides have been uniformly distributed in all of the slots on the armature surface with one coil side in each slot. If the other circuit is continued in the counter clockwise direction to a negative brush it will be found that this circuit has included the other half of the armature coils. These coil sides have also been uniformly distributed in the remaining half of all the armature slots. From a positive brush to a negative

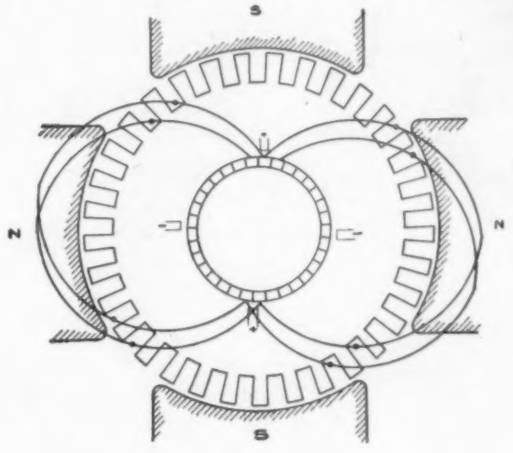


FIG. 1

brush there are two circuits in parallel, each circuit consists of coil sides which are distributed under all of the poles. Hence if there is any inequality in the amount of magnetism in the different poles, both circuits are affected alike.

In the early days when slotted armature cores were first developed, the series winding was used almost exclusively, as machines were all of moderate capacity. The series winding is still in use on motors and generators of the smaller sizes.

As larger sizes were developed, this winding was still used but was modified by using two or more wave windings on the same armature core and arranging them to operate normally in parallel at the brushes. In some cases these windings were entirely independent of each other and were known as "sandwich windings." In other cases the various circuits closed on each other and were called "reentrant windings." These two types of parallel

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

†Engineer, Allis Chalmers Mfg. Co., Milwaukee, Wis.
‡Engineer, Allis Chalmers Mfg. Co., Milwaukee, Wis.

wave windings were tried by several companies, both in this country and abroad, and after shop tests which were apparently successful, the machines were placed in commercial operation. In many cases where a double series winding was used it was found that after the machine had been in operation for several weeks every alternate bar was burned. If bars were marked and commutator turned, the machine would again operate successfully for a while and then burning would occur on every alternate bar, but not always on the same set as before.

This type of winding was abandoned in this country except on machines of moderate capacity. In Germany, however, Prof. Arnold developed a system of cross connectors which overcame to some extent the burning of alternate bars. This system consisted in the inter connecting of various points of approximately the same potential in the different circuits. The elimination of this burning action depended to a great extent on the number of cross connectors used.

After the multiplex series windings proved unsatisfactory the type of winding which was next tried was the parallel or lap winding.

In this type of winding, the ends of an armature coil, which may consist of one or more turns, are

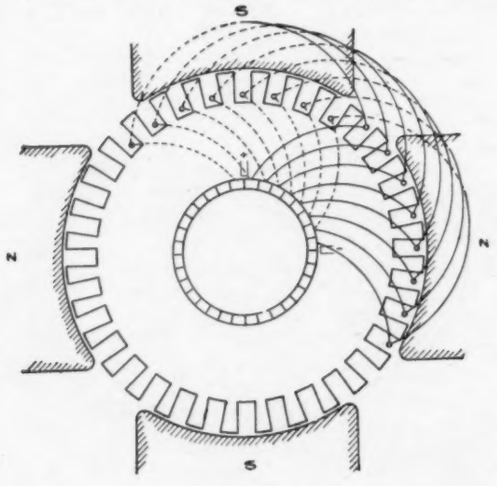


FIG. 2

connected to adjacent commutator bars as shown in Fig. 2. The coil sides, as is the case with the series winding, are placed in slots approximately one pole pitch apart, but the ends are brought to adjacent commutator bars instead of being spread apart two pole pitches. In tracing the circuit from coil end attached to bar under positive brush, the first coil side lies in bottom of slot under leading edge of south pole. The second coil side lies in top of slot under leading edge of north pole. The coil end is fastened to next adjacent commutator bar. In continuing the tracing of the circuit to the negative brush it will be found that the coil sides occupy the lower half of all slots under one south pole and the upper half of all slots under one north pole. In continuing the tracing of the circuit in the same direction from the negative brush to the next positive brush, the coil sides occupy the lower half on slots under the same north pole and the upper half on the slots under the next south pole in the direction of rotation. In this type of winding there are as many circuits as there are poles.

In the series or wave winding only two brush studs are necessary, although more than two are sometimes used. In the parallel or lap winding there are as many brush studs as there are poles.

When this type of winding was first used, it was soon noticed that the commutating conditions were sometimes poorer than in machines of similar capacity with series wound armatures and especially on machines with a large number of poles. It was discovered that some brush studs carried more current than others with the resulting sparking and glowing of the brushes. This was found to be due to unequal voltages generated in the parallel circuits and a careful adjustment of the air gaps under the various poles was necessary. In some cases, where there were found inequalities in magnetic circuit, caused by blow holes in the yoke or poles, individual adjustment of the field coils was found necessary in order to balance up the field strength under the different poles.

In this type of winding the field strength of only one pair of poles affects one armature circuit, while in the series winding each circuit is affected by the field strength of all poles, and there could be considerable variation in strength without affecting the balance of the two circuits. The inequality of the voltage generated in the circuits of the parallel or lap winding was remedied by the use of cross connectors located either on the back of the commutator necks or on the back end or U-bend of the armature coils. These cross connectors are used to interconnect various points of equipotential in the different parallel circuits and thus balance the voltages by providing a path for equalizing currents.

At first the number was as few as three per pair of poles and it was found in some cases that bars would be burnt at symmetrical places around the commutator midway between cross connected bars, and an increase in the number of cross connectors was found necessary in order to eliminate the burning of bars.

As machines were designed with larger capacities and with larger number of poles, it was found necessary to increase the number of cross connected bars. With machines of the largest capacities it has been found necessary to cross connect for every armature slot in order to eliminate blackening of bars between cross connectors.

As the capacity and speed of direct current generators was increased it was found that even with the parallel lap winding there were certain limitations in design. Either the voltage generated per coil, i. e., between adjacent commutator bars, was too great or the amount of current per circuit was too great for succesful commutation. The effect of too high a voltage per bar was the flashing over from one brush stud to the next stud and the effect of too much current to be commutated per bar was glowing and sparking of the brushes.

In order to reduce the voltage between commutator bars, the most effective method up to the present time has been the use of twice as many bars as armature coils. The ends of a coil are connected to alternate bars, leaving a dead bar in between. From the back end or U-bend of the coil a conductor is brought under the armature core and con-

nected to the dead bar located between the ends of the coil. In this manner the voltage between adjacent bars is equal to that of one conductor or one-half the voltage generated by a coil. This method is very complicated and the cost is prohibitive in most cases so that its use has been very limited.

In order to reduce the current per coil, armatures have been made lap wound with two independent circuits between adjacent brush studs and connected in parallel by the brushes. In this type of winding, one circuit is connected to the odd bars and the other circuit is connected to the even

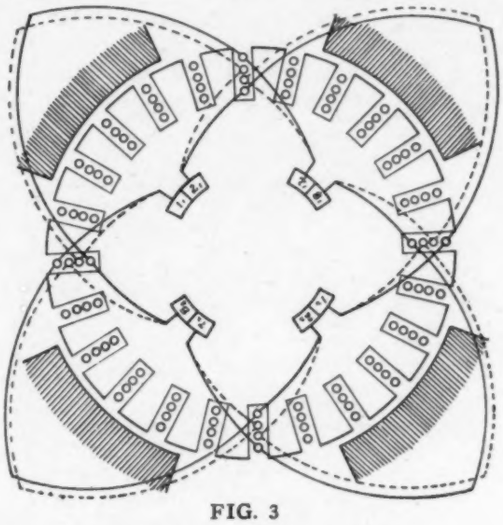


FIG. 3

bars. In this type of sandwich winding, as was the case with the sandwich and re-entrant windings of the wave or series type, one winding would sometimes grab the load and cause burning of alternate commutator bars. And it was found necessary to interconnect equipotential points in each circuit in order to have successful commutation.

The most successful method of doing this has been the riveting and soldering together of the armature coils in pairs at the U-bend and then connecting the ends of each coil so as to leave one bar between the ends. The pair of coils which are fastened together at the back and must have their respective coil sides in the same slots, so that the coil bundle must consist of one or more pairs of coils. This method proved satisfactory in many cases where the current per commutator bar has been too large for successful commutation with a single parallel winding, but although the number of bars is doubled, the bars are in pairs at the same potential and the average voltage between the pairs of bars is the same as if there were only one-half the total number of bars as is the case with the ordinary parallel lap wound armature.

The state of the art in the winding of direct current armature has been briefly narrated up to the present improvements which will now be described.

It has been shown that for parallel or lap wound armatures, especially for large multipolar machines, it is necessary to use equalizing or cross connectors between equipotential points, and the more completely the circuits are cross connected the better will be the equalization of the currents under the different brushes.

It is evident that, if every commutator bar is interconnected with every other bar of the same potential, as perfect equalization of the armature currents will obtain as may be attained with cross connectors. If this is attempted in any machine except those of the larger capacities, it will be found impractical or too expensive to cross connect every commutator bar at the back end of every coil at the U-bend.

In the method of obtaining perfect equalization which will now be described, there are no external cross connectors at either the front or back end of the armature.

In the simplest form of this new type of winding, Fig. 3 represents a four pole armature in which are shown the two windings connected to each commutator bar. The winding represented by dotted lines is a lap winding and that represented by a solid line is a wave winding.

It will be noted that between bar 1_1 and bar 2_1 is a lap winding and between bar 1_1 and bar 2_2 is a wave winding. Tracing the coil sides for the lap winding and the wave winding it will be found that on one side they are in the same slot and on the other side they are in slots diametrically opposite and hence both coils are generating the same potential, providing the magnetic circuits are of the same strength. Both of these coils are potential generating, current carrying circuits, and if made of

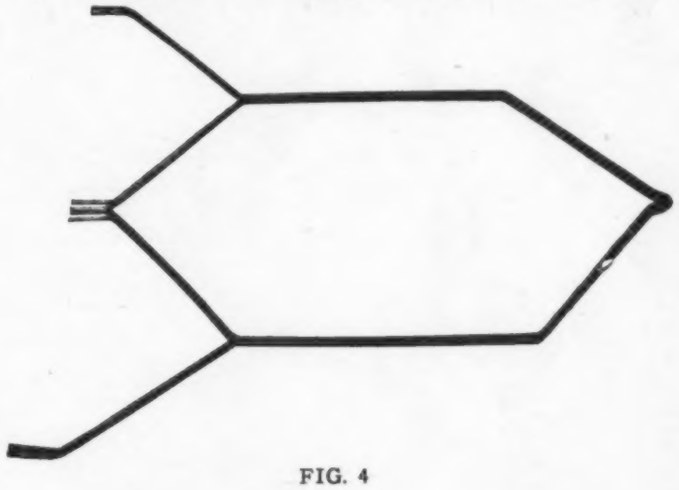


FIG. 4

the same size of conductor, each will have the same resistance and generate the same potential and carry the same amount of current.

Tracing the circuits from bar 1_2 it will be noted that there is a lap coil from bar 1_2 to bar 2_2 and a wave wound coil from bar 1_2 to bar 2_1.

Bar 1_1 is thus connected with bar 2_1 and bar 2_2 with equipotential generating coils and bar 1_2 is connected with bar 2_2 and bar 2_1 with equipotential generating coils.

Thus it is apparent that the same result is obtained as if there was lap winding only between bar 1_1 and bar 2_1 and between bar 1_2 and bar 2_2 and bar 1_1 was cross connected to bar 1_2 and 2_1 cross connected to bar 2_2. Every bar is thus interconnected with every other equipotenial bar without any external cross connectors.

It will also be observed in Fig. 3 that the lap coil connected to bars 7_2 and 8_2 occupies the same slots as the wave coil connected to bars 1_1 and 2_2.

These two coils although they must be insulated from each other can be taped together as shown in Fig. 4, and thus form a single coil unit. It is from the appearance of this coil unit with two coil ends bent toward each other and the other coil ends spread apart, that the winding has acquired its name of "Frog Leg" winding.

In order to show in a simplified manner the essential difference between a cross connected armature and a frog leg, there is shown in Fig. 5 a portion of a developed lap winding.

This shows two coils with coil sides symmetrically located with respect to two pairs of poles. The coil ends A, C, B, and A_2, C_2, B_2 are out of the magnetic field and are generating no voltage.

In the ordinary armature, if cross connected at the back end, a pair of conductors would be fastened to each coil at C_1 and C_2 and after the armature is wound, one of each pair of conductors is bent toward each other and joined at D. On account of the angular span of two pole pitches it is evident that except in the very large machines with many poles, it is impracticable to connect every coil with cross connectors.

Suppose for the sake of simplicity the conductors 2_1, B_1, C_1 and 1_2, A_2, C_2 were made of two conductors in parallel, each of one-half the width of a single

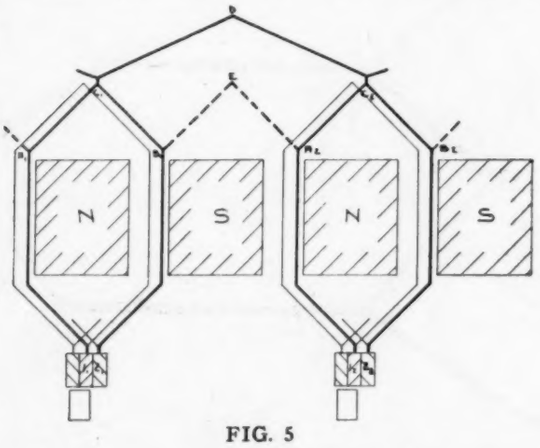


FIG. 5

conductor and arranged in the slot one above the other, or, in case single conductors were used they are split from C_1 to B_1 and C_2 to A_2 respectively.

If now, one of each of the two parallel conductors or one-half of each split conductor is bent at B_1 and A_2 toward each other and joined at E, it is evident that the two coils are cross connected and the connection C_1, D, C_2 is not necessary and furthermore every coil on the armature if made in this manner is cross connected without requiring any more space on the back end than an armature without external cross connectors.

On account of the difficulty in making soldered joints at C_1, E, C_2 after armature is wound in the actual machine there are used a lap coil 1_1, A_1, C_1, B_1, 2_1 and a wave coil 2_1, B_1, E, A_2, 1_2 which are insulated from each other and the electrical connection is made at the commutator bars.

Cross connectors are dirt catchers and are the most difficult part of the armature winding to insulate or to clean and if obliged to carry abnormal currents due to inequalities of the magnetic circuits, they become overheated, roast out and ground or short circuit and very often it is necessary to strip the entire armature winding in order to repair same. In some cases short circuits in cross connectors back of the commutator have been so violent as to weld commutator bars together and thus increase the delay and expense of repairs by causing commutators to be rebuilt in addition to rewinding of armature.

An armature winding which has no external cross connectors, but which is equivalent in construction to one which is one hundred per cent cross connected, is certainly from the operating standpoint an advance

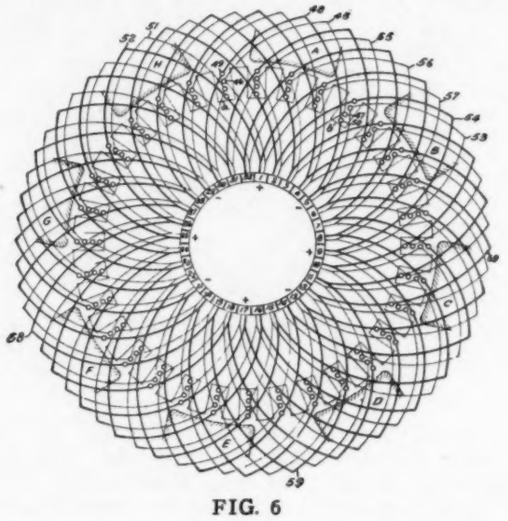


FIG. 6

in the state of the art, if for no other reason. The frog leg winding, from tests which have been made is apparently better than one which is merely cross connected, as it improves the commutation in other ways.

In order that the other features of this winding may be better understood, it will be described as applied to an eight pole armature.

In Fig 6 is illustrated a machine with eight poles indicated by letters A to H and the armature has thirty-two slots in which are wound sixty-four coils. Of these coils thirty-two form a simple lap winding and the other thirty-two form a simple wave winding. The lap winding is drawn in light lines and the wave winding in heavy lines so that they may be readily distinguished. We thus have a single armature with a single commutator to which both a lap and a wave winding is connected. Brushes may be placed at the commutator at the places marked with the positive and negative signs. In the illustration it will be noted that the coils have been so wound that the lap coils occupy the central positions in the slots and the wave coils the outermost and innermost positions. This is done for convenience in winding because the wave coil 48 and the lap coil 45, for example, can then be readily taped together to form a single coil-unit such as shown in Fig. 4.

In order to show how in the winding of Fig. 6 the lap and wave coils are balanced against each other

there is shown in Fig. 7 a portion only of the winding shown in Fig. 6.

It will be noted that the group of four lap coils 45, 55, 56, 57, connected to the commutator segments 1 to 5, has connected at its terminals, that is, to segments 1 and 5, the group of four wave coils 52, 58, 59 and 60. There are then between segments 1 and 5, four lap wound voltage generating, current carrying, lap wound coils with coil sides under poles A and B, and also four wave wound, voltage generating, current carrying, wave wound coils with coil sides under poles H, G, F, E, D, C, B, A. If all of the poles are of the same magnetic strength, the voltage generated by each circuit will be equal, and as the resist-

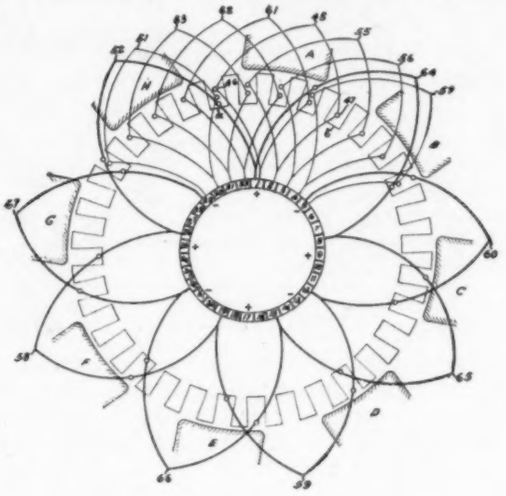


FIG. 7

ance of the circuits are equal, the currents will be equal. If the magnetic strength of the poles is not equal, the current flowing in the two circuits will be proportional to the voltage generated, which in the lap coils is dependent on one pair of poles, and in the wave coils dependent on the average of all the pairs of poles. In Fig. 6, there is also shown the four lap and wave coils between segments 1 and 29 in which the same conditions obtain as between segment 1 and 5.

In Fig. 6, for the sake of ease in tracing the circuits, there is shown only a portion of the winding which starts at segment 1. In Fig. 5, the complete winding is shown and it is evident that similar circuit could be traced starting at any other segment, as for example, 2 to 6 and 2 to 30, 3 to 7 and 3 to 31, 4 to 8 and 4 to 32. Excellent equalization is therefore secured. Added to this equalization we also have every commutator bar interconnected with every other equipotential commutator bar by voltage generating, current carrying armature coils. For example, referring to Fig. 5 from bar 1 to bar 2 we have lap coil 45 and from bar 2 to bar 9 we have wave coil 54. The equipotential bars 1 and 9 are thus interconnected through these two coils. The same is true in a similar manner for every other bar.

Fig. 8 is a photograph of a section of a frog leg winding showing one complete coil and parts of two other coils which occupy the same slots. It will be noted that the coil ends of the complete coil are A, B, C, D. The coil side for A and B occupy the bottom of the slot and coil side for C and D occupy the top of the slot.

For smaller armatures where it is necessary to use more than one turn per coil, the frog leg coil can be also used.

Fig. 9 is a photograph of a two-turn frog leg coil for an armature for a six pole, 100 kw., 250 volt, 1200 rpm. generator. This armature can be wound without any more difficulty than the ordinary multiple turn wave wound coil, and from actual tests it has been conclusively proved that its commutating characteristics are very superior to the ordinary wave wound armature, or the lap wound with external cross connectors.

In order to obtain successful commutation on direct current generators and motors of large sizes and high speeds and of large intermittent overload capacities, the armature winding should have the following features:

1. It should be of the parallel type and be thoroughly cross connected.
2. The amount of current per circuit should be kept within well defined limits.
3. The volts per bar also must be kept within well defined limits.

The limits in design except in a few isolated cases have, therefore, been confined to the use of the ordinary parallel type of armature winding, with one coil per commutator bar and not more than one cross connection per armature slot.

Thus far there has been described the application of the "Frog Leg" winding to this type of armature. It has been shown that with "Frog Leg" windings every commutator bar is interconnected with every other equipotential commutator bar without the use of any external cross connectors either at back of commutator or at U-bend of coils. This winding can also be used on armatures with duplex, triplex or quadruplex parallel windings and equally successful results obtained, as regards the interconnection of the

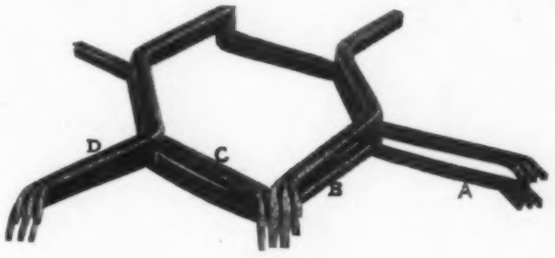


FIG. 8

different circuits. The method of winding used in obtaining results will be fully explained later.

The maximum capacities of large machines for a given speed or the maximum speed for a given capacity can be materially increased by the use of multiplex "Frog Leg" windings since:

1. The voltage between adjacent bars can be made equal to approximately one-half of the complete armature coil, and if conditions demand it, the voltage may be made one-third, one-quarter, or a smaller fraction of that of one complete coil and there are no external connections from back end of armature under the core to the commutator.

2. The number of circuits between adjacent brush studs can be made two, three or four or more and each coil in these windings is so interconnected with every equipotential coil that there is a perfect division of the current between the various windings so that no burning of alternate bars occurs, and there are no external cross connectors of any kind whatsoever on the armature.

In accordance with the formulas, which are deduced in the latter part of this paper, the company with whom the writers are associated have constructed machines of various capacities and speeds embodying, simplex, duplex, triplex and quadruplex frog leg windings.

Part II

The following is some test data on an 8 pole generator rated at 1,000 kw., 250 volts, 4,000 amp., 750 rpm., 50 per cent overload two hours. The armature on this generator was wound with a quadruplex frog leg winding, which means that instead of eight circuits as in the ordinary winding, there are 32 lap wound circuits and 32 wave woung circuits.

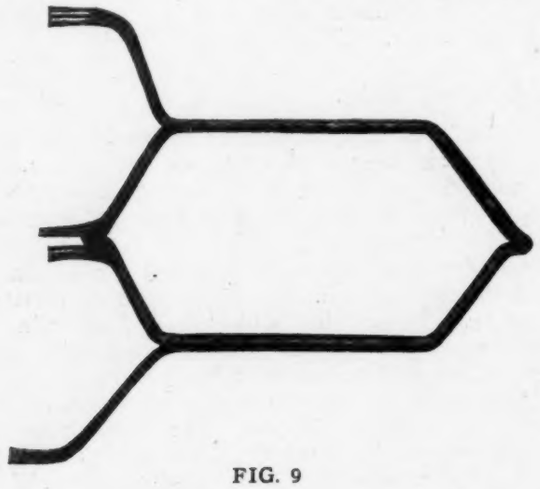


FIG. 9

A comparison of the two windings will be of interest:

	Simplex lap	Quadruplex Frogleg winding
Number of poles	8	8
Number of Circuits in armature	8	64
Amperes per circuit at normal load	500	62½
Number of commutator bars	104	420
Average volts per bar	19.25	4.8
Maximum volts per bar	32	8

From the above data it is apparent that if wound as a simplex lap, the current per conductor, and the maximum volts per bar are both too large for successful commutation, especially for swinging overloads. The above machine was actually tested at 100 per cent overload with black commutation. The volts between adjacent bars was actually measured and the maximum voltage was found to be 8½ volts.

In order to prove the value of the winding with an unbalanced magnetic field, the shunt coil on one pole was short circuited and in addition a set of brushes were removed. These brushes were located opposite another pole. In this condition, the load was increased to 5,600 amperes or 40 per cent overload when the circuit breakers tripped. Under these conditions there was no visible sparking from no load to overload. It was also found that the brushes could be moved at very considerable distance both ahead and back of the neutral without affecting the commutation. This means that on a single generator, the amount of voltage regulation, i. e., compounding, can be varied to suit the particular conditions of operation by moving the brushes and without affecting materially the commutation.

The following data was obtained from tests of two machines of same identical construction except one armature "A" was wound in the ordinary way, three coils per slot and cross connected every slot, i. e., every third bar. The other armature "B" was wound with frog leg coils, no external cross connectors.

	MACHINE "A"	MACHINE "B"
Load	276 volts 2727 amp. 4 hrs	Load 252 volts 3600 amp. 4 hrs
	278 volts 3450 amp. 2 hrs	250 volts 3850 amp. 2 hrs
Temperature Rise—		
Armature surface	44.5 degrees C.	34 degrees C.
Armature copper	50 degrees C.	42 degrees C.
Commutator	66 degrees C.	46 degrees C.
Shunt Coils	40 degrees C.	35 degrees C.
Series Coils	37 degrees C.	37 degrees C.
Interpole coils	44 degrees C.	53 degrees C

The decreased temperature rise in armature windings is due to the elimination of load losses which are carried by circulating currents in armature conductors, and the reduction of eddy current losses in the conductors due to splitting them into two circuits. The reduction of temperature rise on commutator of 20 degrees was due to elimination of short circuit losses in brushes and improvement in the commutation which in the frog leg winding was absolutely black on a subsequent test up to 5,000 amperes. The increase in temperature of interpoles was due to the increase of 11 per cent in current in machine "B."

On account of the wider commutating zone with black commutation on an armature wound with frog leg coils, there is an easy method of changing the speed regulation of motors by shifting the brushes. This is particularly desirable on motors used for hot strip drive where close speed regulation is necessary.

Fig . 10 shows the load speed regulation curve of a shunt wound, 750 hp., motor with speed range 120 to 210 rpm. by field control. The upper set of curves were taken at 210 rpm., and at different brush positions on neutral and back of neutral in order to obtain a rising speed characteristic up to full load and then dropping at over-loads. The curves indicate that stable operation is obtained and with a sudden heavy overload there would be no tendency for motor to grab the load and run away. On the lower curve a full field was taken on the neutral only to show difference in regulation at low speed and high speed.

Fig. 11 shows the load speed regulation curve of a 3,000 hp. double motor with speed range 150 to 300 rpm. This twin unit has its armatures operated in parallel with shafts coupled together and the fields are controlled by one rheostat. There is a slight amount of compounding as a drooping load speed curve is desirable in order to obtain satisfactory parallel operation. It will be noted that on the low speed, i. e., 150 rpm., the drop in speed from no load to full

load can be varied from 1 per cent to 5 per cent, i. e., from 1½ rpm. to 7½ rpm., by shifting the brushes and without affecting the commutation.

On the high speed with weakened shunt field, the compound winding has more effect and in this case the drop in speed from no load to full load can be varied from 5½ per cent to 15 per cent by shifting brushes and without affecting the commutation. A series of tests were made on this 3,000 hp. double unit in order to observe its commutation characteris-

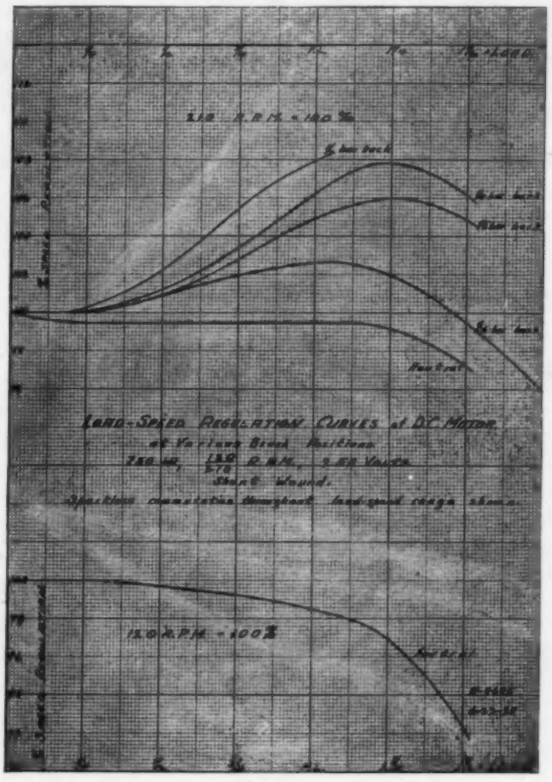


FIG. 10

tics under abnormal conditions. In these tests one-half of the twin unit acted as a motor and the other half acted as a generator. The unit was driven by a belt from another motor in order to furnish power for the losses. Each half of this twin unit had 12 poles and full load rating of each armature was 4,800 amp., 250 volts.

Test No. 1. Unit was operated at 300 rpm., 250 volts with field weakened on both generator and motor. Each armature carried a load of 10,000 amp., over 100 per cent overload, with black commutation.

Test No. 2. Unit was operated at full field, 150 rpm., 250 volts, and the shunt field coil on one pole was short circuited. The load was started at 0 and gradually increased to 8,800 amp., on each armature with black commutation.

Test No. 3. Unit was operated as before with one field coil short circuited and all of the brushes lifted from the brush stud, four poles away from the pole with the short circuited field coil. The load was again started at 0 and gradually increased to 9,800 amp., and held there for about 6 minutes when the driving motor and the belt both indicated that they would not stand any greater overload. In this abnormal condition of operation from zero to over 100 per cent overload, the commutation was black and the only visible signs of load on the machines were the indications on the ammeters, the sparking at brushes of driving motor and the condition of the driving belt.

The set was quickly shut down and thermometers placed on armature coils of the motor which had the short circuited field. The bulb was covered with putty and the maximum temperature (not rise) was 55 deg. C. This indicated very conclusively that, even with the distorted field, the circulating currents were not of sufficient magnitude to overheat the armature as would have been the case with an ordinary lap winding with cross connectors.

From these tests it is apparent that the frog leg coil has one of the good features of the ordinary series wound armature, in that a field coil can be cut out in case of emergency. This has been done in the smaller wave wound mill motors, where one of the fields has become grounded or otherwise injured, and it has been found inadvisable to immediately replace the defective coil on account of operating conditions.

Where this same "first aid" treatment is applied to the lap wound armature, violent sparking at brushes

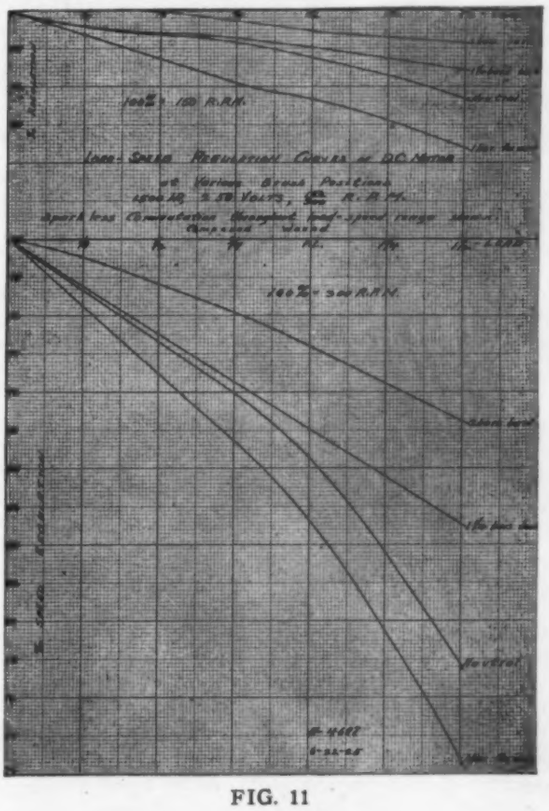


FIG. 11

usually results, and in addition there is overheating of armature conductors and cross connectors, if motor is operated at normal load. In the case of the frog leg winding, a motor with one field coil cut out, could be operated at normal load for any reasonable time with but slight increase in heating of armature. In fact the greatest increase in heating will be in the shunt field coils if the motor is operated at full field, low speed. In this case the shunt field current is increased as the resistance of the field winding has been decreased by short circuiting one field coil.

Part III

Assuming that is is desired to make the voltage between adjacent commutator bars equal to approximately one-third of that generated by one complete coil or winding element, a winding such as illustrated in Fig. 12 may be used.

This winding is of the triplex type, half of the coils forming a triplex lap winding and the other half a wave winding. The triplex lap winding comprises three "sandwiched" simplex lap winding which have been distinguished from each other by the light full lines, the dot-and-dash lines, and the dotted lines. The wave winding is in heavy lines. If we begin tracing with bar 1 and trace through lap coil 68 and continue through the lap winding of which this coil forms a part in a clockwise direction through five of the coils we reach and trace through the lap coil connected to the bars 13 and 16. This coil is not disposed with respect to pole C in the same position as is coil 68 with respect to pole A, in fact it falls two places short (as far as the lap coils are concerned) of the symmetrical position, that position being occupied by coil 71 of the dotted lap winding. It follows

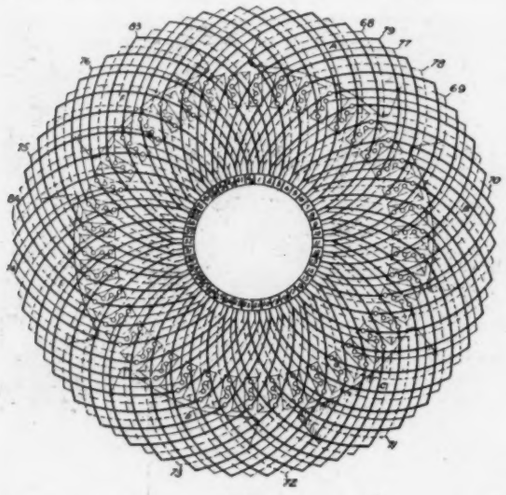


FIG. 12

that coil 71 will generate the same voltage as coil 68 assuming equality of field strengths under poles A and C. Also, the lap coil 74 in the light full line winding occupies the same position with respect to pole E as do coils 68 and 71 with respect to poles A and C. Considering the manner in which the individual simplex lap windings are distributed around the periphery of the armature, it will be observed that what may be termed the field displacement between any two adjacent coils, is so chosen that the summation of field displacements between poles of similar sign may be regarded as less than, greater than or, in any event, unequal to 360 electrical degrees, so that a coil in a simplex lap winding different from that of a coil under a pole 360 electrical degrees distant will assume a symmetrical position with relation to its respective pole at any given instant. In spite of this inequality the total summation of field displacements of any given simplex lap winding must be equal to the product of the number of pairs of poles times 360 electrical degrees, or double or more than that amount, if it is desired that the winding itself shall be more than singly re-entrant. It may therefore be stated in general, that the individual lap windings are so interleaved or "sandwiched" that the active conductors of one winding are adapted to pass a given polar position while active conductors of another winding are passing a similar polar position.

The conditions above pointed out may be obtained by observing the proper determining factors in selecting the number of poles, coils, number of individual windings, etc. A consideration of these determining factors may be obtained as follows:

If the total number of coils is designated by C, the number of pairs of poles by p, and the number of windings by m, the following relation may be deduced from Fig. 12. The number of coils in the lap windings collectively per pair of poles, $\frac{C}{p}$, and also, the number of the former as simplex winding, $\frac{C}{m}$ should preferably be an integer but $\frac{C}{\frac{p}{m}}$ must not be an integer.

That is, the number of coils per pair of poles is an integer not divisible by the number of windings. This quotient may be expressed as follows:

$$\frac{C}{\frac{p}{m}} = a + \frac{b}{m}.$$

Referring to Fig. 12 it will be noted that the integer b in the above formula represents the number of coil positions that the fifth lap coil (in tracing from bar 1 through the dot-and dash winding as hereinabove described), falls short of assuming the position of coil 71. Integer b may be any number less than m. Specifically, in Fig 12,

$$\frac{C = 42}{\frac{p = 3}{m = 3}} = a + \frac{b}{m} = 4 + \frac{2}{3}.$$

In this case b = 2 which agrees with Fig. 12. The condition,

$$\frac{C}{\frac{p}{m}} = a + \frac{b}{m}$$

applies equally well to cases where the number of lap windings, m, is other than 3 as in Fig. 12, that is, it may be 2, 4 or any desired whole number.

A general expression may be obtained for the proper number of coils per simplex winding, irrespective of the number of poles, as follows:

$$\frac{C}{\frac{p}{m}} = \frac{me}{md} = \frac{e}{d} = \frac{\text{an integer}}{m}$$

which quotient must not be an integer. Here e equals the number of coils per simplex winding and d equals any whole number. That p = md follows from the fact that the total number of poles (2p) should be equal to 2md, inasmuch as there must be at least 2m = 4 poles for a duplex winding, 2 m = 6 poles for a triplex winding, etc.

In the case of slotted armatures, the number of slots should be governed in a manner similar to the number of coils C, for example; that is, the number of slots per pair of poles should be an integer not divisible by the number of lap windings. A fur-

ther condition is that if the number of coils per slot is greater than one, the number of coils per slot must be so chosen as to be prime to the number of windings. For example, for a duplex winding the number of coils per slot should be 1, 3, 5, 7, etc.; for a triplex winding the number should be 1, 2, 4, 5, 7, etc.

A triplex lap winding such as shown in Fig. 12 may be efficiently cross-connected by external cross-connectors for the reason that there are equipotential points in the individual simplex windings which are located at the same end of the armature. Such windings have been made and have operated successfully. It is, however, advantageous, as has been pointed out, to eliminate external cross connectors, not only from a manufacturing standpoint, but also because even better results, electrically, are secured by the new type of winding. We come now to the wave or series winding, which is combined in the proper manner with the triplex winding of Fig. 12. The conductors belonging to the wave winding are in this instance the uppermost and lowermost in the slots. If we trace through this wave winding from a given commutator bar we will pass through all the conductors belonging to that winding before we again reach the starting point. (It may be noted at this point that under certain conditions this would not be the case and the wave winding might

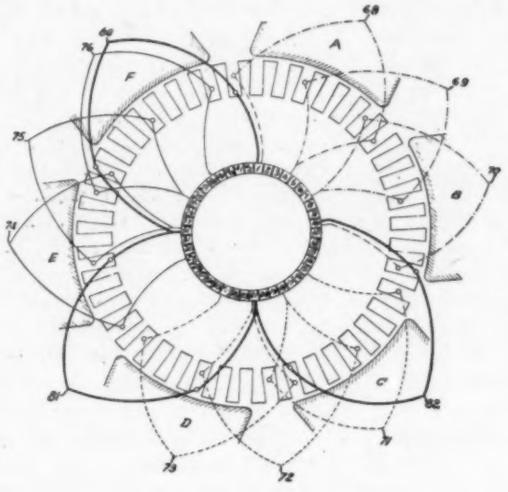


FIG. 13

be of multiplex form.) In doing this, however, we have gone around the armature nine times, that is, the winding is nine-foldly re-entrant and therefore has eighteen circuits. As triplex winding has three times as many circuits as the number of poles, the wave winding has the same number of circuits as the triplex winding. The proper number of circuits for the wave winding is obtained by selecting the proper front and back conductor pitches of the wave coils and the commutator pitch of these coils. Viewed from another angle, the span or slot pitch of the wave coils is selected for the best results, so as to be equal to the difference between a slot pitch of 360 electrical degrees and the slot pitch of a lap coil. If the latter slot pitch is equal to 180 electrical degrees, then of course the slot pitch of the wave coils is the same, and this is the case in Fig. 12.

In order to show how the lap and wave windings mutually equalize each other, and more specifically, how the wave winding equalizes the individual components of the triplex lap winding, a portion only of the winding of Fig. 12 is shown in Fig. 13.

There are here shown three coils 68, 69, 70 of the dot-and dash lap winding, three coils 71, 72, 73 of the dotted line lap winding, and three coils 74, 75, 76, of the light full line lap winding. For reasons which have been hereinabove set forth, these groups of coils occupy symmetrical positions with respect to the poles. It will be noted that for every commutator bar touched by the group of lap coils 68, 69, 70 there is a bar in each of the other groups of lap coils shown which is at the same potential, assuming of course that the field strengths of the poles are equal. One group of wave coils, 80, 81, 82 has been shown, this group beginning at bar 1 and ending at bar 10. It will be noted that for every wave coil in this group there is also a lap coil in the group 68, 69, 70 which has exactly the same position with respect to the poles. The potential difference generated in the group of wave coils 80, 81, 82 is therefore normally equal and opposite to that generated by the group of lap coils 68, 69, 70, these groups being connected at their terminals at bars 1 and 10. As has been similarly pointed out in connection with Fig. 6, the voltage generated by coils 68, 69, 70 is dependent on the magnetic strength of one pair of poles, A, B, whereas the voltage generated by coils 80, 81, 82 is dependent on the average strength of all of the pairs of poles. The chances for the flow of equalizing currents is therefore minimized. What has been stated in connection with these groups of coils is also true with respect to any other group of three consecutive lap coils. But the group of wave coils 80, 81, 82 is connected not only to the group of lap coils 68, 69, 70, but is also connected to bars 32 and 21, the first of which has connected thereto coil 74, for example, of the light full line lap winding and the second has connected thereto, for example, the coil 73 ot the dotted lap winding. The components of the triplex lap winding are therefore interconnected by the wave coils. It will be noted, considering one of the interconnecting paths, that the bars 1 and 32 to which coil 80 is connected are not equipotential bars, but bars 1 and 29 are such bars. There is a path from bar 1 through coil 80 to bar 32, then through lap coil 74 to bar 29. Both of these coils are normal potential-generating load-current-carrying coils but the potential differences generated are normally equal and opposite so that no equalizing current flows between bars 1 and 29. Should, for any reason, these potential differences become unequal, an equalizing current will immediately flow and it must be borne in mind that this equalizing current is one entirely separate and distinct from the normal load-current flowing in the coils in question. The equalizing paths and balanced groups of coils thus far described are sufficient to show how thoroughly such a frog leg winding is equalized and balanced. As far as the division of voltage as between adjacent commutator bars is concerned it may be stated that as a matter of calculation, and proof by actual test, it has been shown that for a triplex winding the voltage between adjacent

bars will not rise above one-third of the maximum voltage generated by a single winding element or coil. If the voltage is measured from one brush, bar by bar to the next brush, a smooth curve of voltages will be obtained, thus showing how evenly the total voltage is divided by the commutator bars.

*How the Electrical Engineer and the Safety Engineer can be Mutually Helpful**

By JOHN A. OARTEL†

THE application of electricity to modern industrial transportation and to general living conditions has truly been marvelous, and if the advancement of this science during the next fifty years equals that of the last half century, I think we can truly say that we live in the age of miracles. We, who are here today, are particularly interested in one phase of electricity only, namely, its application to the iron and steel industry. I think there are a number of men in this gathering who can remember when the only use to which it was put in a steel mill was to furnish light of a very uncertain quantity and quality. I refer to the old-fashioned arc light. It may be that there is at least one person here whose duty it was to go around at night in a steel mill with a long pole and shake the carbons into renewed activity. What do we see now? We see electricity as the actuating principle in all our steel mill operations, beginning with the electrical car dumper and transfer car at the blast furnace and ending with the magnet that deposits the finished or fabricated product in a railroad car ready for shipment to its destination.

The electrical engineer in the steel mill today is concerned not only with the continuous and efficient operation of a few isolated units, but with the continuous and efficient operation of the entire plant. If the "juice" fails, the mill goes down, and the electrical engineer is "out of luck." I desire to add another responsibility to his already burdened shoulders. To continuous efficient operation of the plant, I want to add—safe operation. American Industry has learned to its abiding credit that iron and steel can be produced efficiently, in great quantities and—safely. I need scarcely remind you that this organization was responsible for the beginnings of organized safety in this country. You fathered the National Safety Council, which is recognized as the chief promoter of safety, both industrial and public in this country. You now invite the safety engineers from the iron and steel mills to come into your organization in order that our common problems may be happily solved.

I shall not attempt to discuss any of the specific problems that confront the electrical and the safety engineer. I shall leave the detail to be worked out later by those who are better qualified. I shall only emphasize a few general principles, which, if applied, should help both the electrical and the safety engineer and which should bring them closer together in their work.

I had a very unique and helpful experience in safety about a year and a half ago, which made a lasting impression on me. I had the privilege of making a safety survey of ten large steel mills, employing approximately from one thousand to ten thousand men. By using the expression "safety survey," I do not use it in the generally accepted meaning of the term. As commonly understood it means to go into a plant and inspect for mechanical hazards or dangerous practices. I did not go into the plants at all. I went into the Superintendents' dining room at each plant and sat down to lunch with the General Superintendent and all his Department Superintendents and asked them—why in these days of advanced safety they were still having accidents in their particular plant. The answers were many and varied, and I shall not burden you with them in this address. I completed the survey, went back to my office and thought it all over. I then asked myself several questions. The questions were: "Was it worth while?" "Have I learned anything?" and "Did it do any good?" After thinking it all over and having analyzed and visualized the organization at the various plants I had visited, as well as the methods they used and what was said at the meetings, I answered "yes," to all my questions, "it was worth while," "it did some good," and "I learned something."

I learned first, and it is not a new conception by any means, that it is a good thing for men to get together to discuss common problems. The dreadful ravages of war could be avoided; costly litigation could be prevented, and people would be very much more prosperous and happy, if the get together spirit prevailed more generally. I cannot announce definitely what the results of this meeting will be, but I think I can safely prophecy that a better spirit and a clearer understanding will prevail among the electrical and safety engineers from our iron and steel mills, just because we have come together around the council table to meet each other, to look into each others faces and to solve our common problems.

Common problems lead directly to the next thing I learned in my survey which was, I found that the plant where the best co-operation prevailed, invariably had the best safety record. It was so very evident that I could lay my finger on it and say "Here it is." Co-operation is not a new term. It is as old as mankind. It means simply for people to help each other. It means that the man in the mill or in the office shall help his fellowman, and where the greatest co-

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

†Chief of Safety Bureau, Carnegie Steel Company; Director, National Safety Council; Vice President, Western Pennsylvania Division, National Safety Council; President, Pennsylvania Society of Safety Engineers.

operation prevails, there the greatest success is found. It is the spirit of the baseball team of the football team, where all individuality is subordinated in order that the team may win. It is the spirit of the college yell where thousands of young voices rend the air as one voice—to spur the team on to victory. I recently saw this spirit exemplified to a marked degree in a safety drive in a large steel mill employing sixty-five hundred men.

In preparing for the drive the safety director and myself visited every department to meet and talk with the department superintendent, the safety committee and groups of employes. I was particularly impressed with the very able manner with which the electrical superintendent handled the matter. He was not satisfied with anything less than complete co-operation with the safety director. It was not enough for him to bring the safety committee, the foremen and the gang leaders to the office to hear the talks—his ambition was to have his full force hear about the safety drive and to participate in it to the fullest possible extent. He had his entire force come to the electric shop in groups of fifty or a hundred. The shop was provided with seats in order to have the men comfortable during the talks. Safety bulletins, signs and slogans were displayed on the walls. Safety devices used in the electrical department were displayed and their use explained to the men. An orchestra was recruited from the men in the department, which entertained the men while they waited for the speakers. To sum it all up, it was one of the finest examples of co-operation that I have ever seen, and I take pleasure in stating that the electrical engineer, whose work I have been describing, is the President of this organization, Mr. A. C. Cummins. The Carnegie Steel Company has an enviable safety record. That record is not due to the contribution of any one man alone. Mr. Burnett has given his leadership and counsel. I have tried to do my bit. The enthusiasm of the safety engineers at the plants has been remarkable. The burden and the heat of the day, however, has been borne by men in positions similar to that of Mr. Cummins, who have rallied to the work and who have given their whole hearted co-operation.

On the other hand, I wish to tell you of an incident in a steel mill in connection with electrical apparatus, where the lack of co-operation among a number of the men resulted in a fatality. The details of the accident are as follows:

> Two narrow gauge engineers, working on the 3 to 11 turn, whose work was to transport hot billets through a tunnel, discovered that the warning whistle at the mouth of one end of the tunnel was not working. One of them had the Roller blow the whistle to call the electrician, who responded to the call and made an investigation. So far as he could see everything was all right at that end of the tunnel, and he asked one of the engineers to make sure on his next trip that the switch at the other end of the tunnel was all right. There was no further conversation between these two men during the remainder of the turn. At 11 p. m. two other engineers came on the job. One of these noted on his first trip through the tunnel that the whistle did not work. He took such steps as were necessary to call this to the attention of the electrician then on duty. About 2:30 A. M. the foreman of the mill noticed that the tunnel whistle was not working, and the electrician was again called. At that time the electrician who was called, said that the trouble was at the other end of the tunnel, but nothing further was done to put it into service. At 7 A. M. the turn changed again. The foreman had given the whistle no further thought, the engineer left the job without advising the man who relieved him that the tunnel whistle was not operating; the electrician also left the job without repairing it or reporting it to the night electrical foreman. About forty-five minutes later a narrow gauge engineer was on the tracks near the end of the tunnel when another engineer made his first trip through. The crew were depending on the whistle for a warning, as the whistle did not blow they assumed everything was all right. The engineer coming through the tunnel threw the tunnel switch as usual, and had no way of knowing that it was not working, there was a violent collision between the two engines in which a man was instantly killed.

I hesitate to say more about Mr. Cummins lest he become embarrassed. It is better, however, to have in your midst the man who has done the things I am advocating, than to create an ideal which is impractical. That is the reason I am going to say one thing more about him. He said to me, during the course of the meetings I have just described, "I am trying to instill the thought of service into the minds of my men. I am telling them they are the service department of the plant. I am trying to get them to understand that the continuous and successful operation of the plant depends on the character of the work they do." I think if the electrical men here could take home the thought that their work is indeed a service to the entire plant, and if they could spread this among their men, this convention would, indeed, accomplish something worth while.

You as electrical engineers, are all familiar with the harnessing of Niagara. Some of the latent energy that has poured over the falls for ages is now doing useful work. My problem at this stage of my address is to turn the fine spirit of unity and co-operation into something useful down in our various steel plants. This brings me naturally to the last thing I discovered in my survey, which was, that the department doing the most intensive safety work, invariably had the best safety record. By intensive work I mean, the holding of department safety committee meetings; safety instruction by the foremen, either individually or in groups; alertness on the part of all to discover and eliminate dangerous practices—in fact, to do anything that can be done to promote safety.

Work is a term that has fallen into disrepute in late years. The only ambition of a great many people is to do as little work as possible; this is true not only in the steel mills, but also in offices, stores and everywhere business is transacted. While it is true that manual work has decreased, because of the application of science, nevertheless, there is still great need and great demand for men who will apply themselves to a given task. This is particularly true of the work of the electrical engineer and of the safety engineer. The electrical engineer is reaching out into the bound-

less and fathomless ether to find a vehicle to conduct the electron to its destination. Likewise, the safety engineer is delving into the inner workings of men's minds to find out the reason for accidents. The electrical and the safety engineer have both had marked success in their professions in recent years. While they have been close allies in their work, I hope this convention will mark the time when they shall not only be allies but co-workers, each helping the other by a closer co-operation and a better spirit to the achievement of a common aim—efficiency with safety. My earnest wish is that the inspiration and ideas we receive here may be an incentive to more earnest endeavor that will result in greater achievements in the days and weeks to come.

A short illustration in closing will perhaps sum up a few of the vital things I have endeavored to express to you. In a recent safety drive in a steel mill, it devolved on me to secure some speakers. I 'phoned to one of our plants to a department superintendent to get him to make the talks on one of the selected days. His talks were well received and were very successful. The day following the talks he held his own department safety committee meeting. When the minutes came to my office, I read a description of his experience, which he had given to his committee. He said, "Boys, it was my privilege yesterday to go to another plant to make some safety talks. It was necessary for me to get up at five o'clock in the morning in order to arrive at my destination on time. I made five talks and was very much impressed by the interest and enthusiasm in the safety drive, which was displayed at every meeting. I arrived at home at one o'clock in the morning, and I enjoyed every minute of the time." Surely if we can catch the spirit of this man it cannot fail to show results in our work.

---

*Report of Electric Heat Committee for 1925**

By GEO. H. SCHAEFFER, Chairman, Elec. Engr., The Carpenter Steel Company.
E. A. HURME, Manager, Steel Mill Section, Westinghouse Elec. & Mfg. Co.
J. A. SEEDE, Industrial Engineer, General Electric Company.
C. J. CONE, Engineer, Geo. J. Hagan Co.
R. S. SAWDEY, Electrical Superintendent, Van Dorn Iron Works.
G. A. HUGHES, Electrical Superintendent, Truscon Steel Company.

1—Change from Electric Furnace Committee to Electric Heat Committee

THE Association of Iron and Steel Electrical Engineers has taken a vital part in the development of electric heat as a means of melting and treating steel, and in our first annual proceedings, published in 1912, there will be found data relative to this subject.

Due to the increasing use of electric heat in the steel industry, the Association considered it advisable in 1919, to appoint an Electric Furnace Committee to actively follow and make a yearly report on the subject. The first report of this committee was submitted by the Chairman, Mr. R. D. Nye, at the Annual Convention held in St. Louis, in September, 1919. To illustrate the growth of the industry, it should be noted that there were approximately 290 arc furnaces in the United States in 1919, while today the total is approximately 500, an increase of 210 furnaces in six years.

Even greater progress has been made in the development of furnaces designed for medium and low temperature applications. In fact, the question of medium and low temperature furnaces as applied to the steel industry has become so important that our board of directors felt it advisable to change the name of the "Electric Furnace Committee" to the "Electric Heat Committee." Under the new heading, the committee will study application of electric heat in the medium and low temperature furnaces, as well as in the large electric arc melting furnaces.

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

2—Character of Report

The committee this year has endeavored to make a fairly complete review of the various phases of the subject, including a brief history and development, dating from the time of the first installation to the present time. It has been our object to place in the 1925 year book a record that, we hope, may be used as an authentic reference on the subject.

We have put a considerable amount of effort into the report with the view of simplifying future reports. With a review of the subject on record, we believe that future reports need only to add such new developments and improvements as may occur from year to year.

The committee recommends that the different sections make every effort to schedule papers dealing with electric heating subjects, bringing out items of unusual interest and describing in detail any new developments that are made from time to time.

3—Sources of Information

It is not an easy task to accumulate information in regard to a subject that develops as rapidly as Electric Heating. The committee is indebted to the leading manufacturers of heat treating furnaces, who have supplied a considerable amount of data that they consider of especial importance. The committee acknowledges this assistance with thanks, and further adds that without it, this report would have been impossible. Personally, I am indebted to Mr. J. A. Doyle, New York City, for many valuable suggestions and use of his records.

4—Economics of the Heating Problem

In order to see whether "Electric Heat" would stand the acid test, it was thought advisable to deliver this report before the "Combustion Engineers Section." The members of this section, being especially experienced in the applicaiton of various types of heating furnaces, are particularly capable of passing judgment on the best method of heating.

It seems to me that each application of a heating furnace (of any temperature) is a special and separate problem. It is influenced by the peculiar plant conditions and has its own particular duty to perform. These items should be carefully studied and blind duplication of equipment avoided.

We believe that any application requiring the use of a furnace or furnaces should be considered on its own merits, and each application should be carefully analyzed. By this method we can compare the cost of the operation by the use of the most improved equipment using any form of fuel or energy that might deserve favorable consideration.

It is not fair to compare the cost of operation using some old type of equipment with the latest improved design using another form of fuel.

We should cover the field thoroughly and get the costs of production by the use of latest designs, using the different types of energy available.

It is an economic error and a setback to the art to install an electric equipment if some other form of energy will meet the conditions equally well and at a reduced cost. It has been stated that we are after "QUALITY AND COST OF FINISHED PRODUCT." This, we must keep in mind, and on this basis we should win or lose the decision. We further feel that no one particular form of fuel or energy will meet every furnace problem.

The question as to size and number of furnaces —characteristics of electric supply—rate of production—quality—are all easily settled by a study of plant conditions.

The use of off-peak power should receive consideration. The fact that we may use a furnace during the off-peak periods gives us a rate which does not carry a demand charge. On the other hand, it results in a producing unit of rather uncertain reliability and what we might gain by the use of off-peak power, we might more than lose by decreased production.

5—The Attitude of the Committee is that the electric heat can win only on its merits. If it is not a positive gain over any other form of energy, it has no economic justification. Each installation is a separate problem and should be treated as such. The field for electric heat is growing rapidly and particularly that of the medium and low temperature furnaces. The Electric Service Company already finds the heating load more desirable than the motor load per KW demand—and the financial returns, according to N.E.L.A., September, 1924, are in ratio of 2 to 1.

We feel that our members should adopt a conservative and constructive attitude. By being conservative, we will investigate all the possibilities available and construct accordingly.

Mr. John A. Seede, Industrial Engineer, of the General Electric Company, will present his paper on the "Electric Melting Furnaces," after which Mr. E. A. Hurme, Manager, Steel Mill Section, Westinghouse Electric and Manufacturing Company, will trace the developments as they occur from the ingot to the finished product.

As the value of a paper is greatly enhanced by the discussion, we are very desirous of having the whole report fully discussed from all angles—especially by the Combustion Engineers.

---

*Electric Heat Treating Furnace Applications**

By E. A. HURME†

THE interest created at the last convention by the report on "Medium and Low Temperature Applications," together with the continued interest manifested in this subject by the steel industry, seems to justify a continuation of the work started last year. This year the committee has attempted to make the report as complete as possible with the purpose of giving the steel mill engineer data to determine what heating processes in his plant can be economically electrified. Valuable assistance has been given the committee in this work in the form of suggestions and data by manufacturers of heating equipments.

It was decided to include all processes in the iron and steel industry in which heat is required, without limitations as to temperature, such as those observed in the previous report. This report is intended to cover the principal heat treating and miscellaneous applications not classified under melting furnaces, which are covered by Mr. J. A. Seede's report.

Before taking up the various applications of heat treating, a short historical outline may be of interest.

Probably the first commercial development in the application of electricity to an industrial heating process was for heat treating heavy armor piercing projectiles, about 1911. This was a 125 kw. capacity vertical furnace, about 5 ft. high and 30 in. inside diameter. Due to the nature of the products heat treated, this pioneer installation was known only to a few, so it is generally acknowledged that the first real development in the application of electricity to an industrial heating process, was on the enameling ovens used in the automobile industry, about 1914. It is interesting to note that these applications were several years later than the first installation of an electric arc melting furnace. The electric oven for enameling overcame many of the difficulties experi-

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

†Manager, Steel Mill Section, Westinghouse Elec. and Mfg. Co.

enced with combustion ovens and the use of electricity for this process is now almost universal.

From this starting point, the use of electricity for heating was gradually extended. However, not until about the last five years have the advantages of electricity for most heating applications, including many in the steel industry, been recognized.

About 1920 the Electric Service Companies began to give attention to the use of their product—electric power—for heating, and due credit must be given the power companies for their part in developing the art. About this time the manufacturing companies also began intensive research and development pertaining to electric heating apparatus. Thus it may be said that the application and installation of approximately a million and a half kilowatts of electric heating apparatus have been made in the last five years.

In this report we have tried to outline the factors to be considered by the steel mill engineer wishing to review what has been done in the field of electric heating in the steel mills.

Beginning at the melting furnace, and tracing the product through the various processes to its final form, let us consider each process in which heat is required in order to determine the possibilities for electrification.

Soaking Pits

After the ingot comes from the open hearth, or electrical furnace, the first process requiring heat is the soaking pit, where the ingots are brought to the proper temperature and allowed to remain until the temperature becomes uniform.

To the Donner Steel Company belongs the credit for the pioneer installation of an electrically heated soaking pit. This experimental installation was made in March, 1924. A very interesting paper by Mr. T. F. Bailey was presented before the Pittsburgh Section on January 30, 1925, so only a brief summary will be given here.

The electric soaking pit was installed more or less as an experiment in the hope that it would eliminate some of the troubles experienced with gas heated ingots, such as large scale loss, cutting of the ingot by impigning of gas flames, and defects occurring on the surface of the blooms. A noticeable improvement in each of these particulars was credited to the electrically heated pit. In the matter of scale loss, in particular, an advantage was shown for the electric pit, the average loss for electrically heated ingots being ¾ per cent against 1¼ per cent for gas heated ingots. This item is of special importance in high grade alloy steels.

It was demonstrated that the blooms from the electrically heated pit had better surfaces except when the ingots were particularly scabby. It was observed that the power required for rolling the electrically heated ingots was less, although no reason for this could be discerned. A saving in space also was accredited to the electric equipment.

The cost of heating electrically was found not to exceed heating by gas in this particular case, the electric furnace being accredited with the saving in scale loss. This is based on charging the ingots hot. A distinct advantage claimed for the electrically heated pit is that it tends to eliminate discussions between the open hearth and the blooming mill departments as to the source of trouble in the steel.

The Donner Steel Co. soaking pit is of 150 kw. capacity and holds two 6800 to 7400 lb. ingots. The power required to raise the temperature of ingots from an average charging temperature of 1660° F. to 2316° F. and holding at this temperature was 80.4 kw-hr. per ton. As this temperature is above the range of metallic resistors, the heating element is composed of a crushed carbon resistor enclosed in a trough around the wall of the pit. The necessity of renewing this resistor though infrequent, constitutes one disadvantage of this pit. This, however, is probably offset by the more frequent renewal of the refractories in a fuel-fired unit.

It developed during the discussion that conditions at Buffalo were especially favorable to electricity from an economic standpoint, and that the same savings could not be effected in localities having plenty of cheap fuel which might be wasted if not used in the soaking pit. Also it was brought out that the solution of the soaking pit problem might be the installation of more pits rather than the change from gas to electricity. The mechanical construction was open to some criticism, as the resistor support is required to withstand severe shocks in the handling of the ingots. As the electrically heated soaking pit is a new development, future installations will be watched with interest.

Reheating Furnaces

The next heating process in progressive order is the reheating furnace for rail, structural, sheet—bar mills, etc. To date there have been no installations of electrically heated reheating furnaces and as the temperature required is about 2500° F., a furnace similar to the electric soaking pit would be required.

There is a difference, however, between the soaking pit and the reheating furnace which, under present conditions, seemingly would make electricity uneconomical for the latter. In the soaking pit, the ingots usually are charged hot and the only heat required is that necessary to maintain the temperature and allow it to become uniform. In the reheating furnace, however, the work is ordinarily charged cold. A large quantity of heat therefore is required which would, in most cases, be uneconomical to supply by electricity.

In Pair furnaces the pairs or bars are heated to temperatures of from 1100° to 1800° F. The furnace atmosphere must be non-oxidizing, as scale will cause open surface in the finished sheet. Sheet furnaces usually operate at 1400° to 1600° F. In both types of furnaces it is customary to have a heavy smoky atmosphere and most furnaces are coal-fired.

There is a development in the manufacture of sheets at present that would no doubt be a good application for electric furnaces. A number of mills making highly finished sheets for deep drawing automobile stock normalize the sheets at 1650° to 1800° F. This is usually a continuous roll-type furnace. Individual sheets are passed through the furnace and allowed to cool in the open air. Due to the more uniform temperature and the accurate control of the temperature, the electric furnace should give a better sheet. Fewer rejections should compensate for increased fuel cost.

Finishing Processes

Next in order follows a series of finishing processes requiring the application of heat at somewhat lower temperatures. One such is the "pickling" process in sheet and tin mills. "Pickling" is done in a vat usually heated by steam at a temperature of about 500° F. In electrically driven sheet and tin mills it is necessary sometimes to maintain a steam boiler with its cost of attendance and operation, solely to supply heat for this process. There is but little doubt that in such cases a saving could be made by using an electric steam boiler, and such cases are worthy of special study by steel mill engineers.

Also, electric boilers installed for this purpose could be used for heating the plant office buildings. The electric boiler has been used in the pulp and paper industries where cheap power is available. It has an efficiency of approximately 94 per cent and unit power factor. Approximately 10 kw. in boiler capacity is required to generate one boiler horsepower. There is also the possibility of applying heat directly to the pickling solution, but this would require a heating element which would withstand the attack of the pickling solution, and to date no such heating unit is available.

Galvanizing and tinning are done at temperatures below 1000° F., and could be done satisfactorily by electricity if warranted by the comparative cost of electricity and fuel. Little attention has been paid in the past to the control of the temperature for this process. There is, however, some difference of opinion on this point among metallurgists and it is believed by some that the temperature is an important factor. If this is true, an advantage could be shown for electricity which would in some cases justify its use. Electric heat is being used for galvanizing in a small plant at the Mare Island Navy Yard in California.

The Geo. J. Hagan Company has installed an electrically heated tin pot. Over a period of three months the heating costs per base box by the electric furnace were considerably higher than coal. However, the production per pot was increased by 75% and the dross per base box was reduced by 10%. Wasters and menders were materially reduced. The test showed that were a tin house to be built, the saving in floor space, elimination of stacks, coal and ash handling equipment would practically pay for the increased cost of electric equipment. The increased production and saving in dross, and the decrease of wasters and menders would compensate for the increased fuel cost.

Annealing Sheets

For annealing of sheets an elevator-type furnace, illustrated in Fig. 1, has demonstrated many advantages over the fuel-heated furnaces. Previous to the installation of this furnace, work was placed in heavy annealing boxes which are essential in fuel-fired practice and frequently the weight of annealing boxes in the furnace just about equals the weight of the work. The electric furnace is so designed that it can be loaded from the bottom, using for convenience in handling a car, the top of which may be elevated into the furnace by means of a lift. This construction was used in preference to the ordinary car bottom furnace with doors, as it permits effective exclusion of the air from the furnace chamber. Thus the use of heavy steel or iron boxes was entirely eliminated, saving not only the cost and maintenance of such boxes, but also the energy required for heating the boxes. A very material reduction in annealing costs was secured on account of these two factors.

The requirements where this furnace was installed were for uniform annealing of a certain degree with entire freedom from scale. These conditions were fulfilled, and in addition to the savings mentioned above, working conditions were greatly improved. There was also a saving in floor space formerly taken up by the annealing boxes, and, of course, the labor of handling

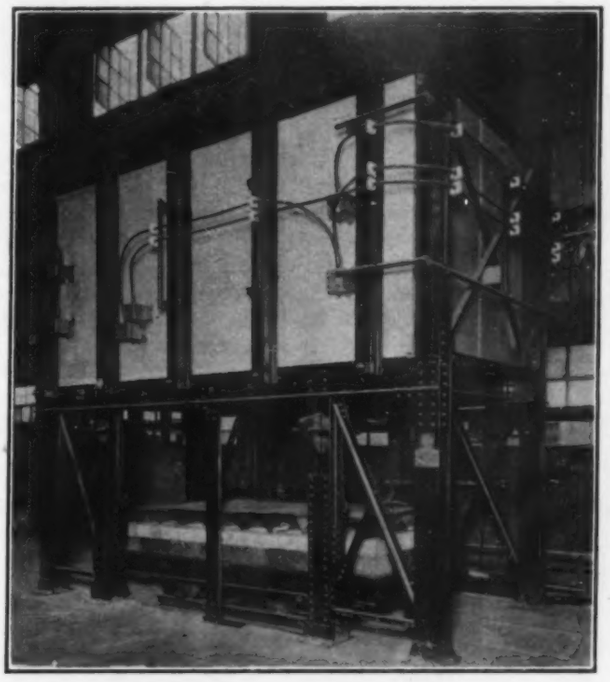


FIG. 1—Elevator Type Electric Furnace for Annealing Steel Sheets.

was reduced. A large manufacturing company has fourteen of these furnaces in use today, having a total connected load of about 2200 kws. One of the smallest of these furnaces has inside dimensions 7 ft. long, 2 ft. wide, 1½ ft. high, with 130 kw. connected. Eleven heats are secured per week of 3½ tons each with an economy of 11 Kwh. per 100 pounds. The annealing temperature used is about 1500° F. and the highest temperature in use for an elevator type annealing furnace is about 1850° F.

Bright Annealing

For bright annealing strip steel an electric furnace equipment was recently installed at the Stanley Works, New Britain, Connecticut, as a test unit to determine the advisability of commercial bright annealing unstripped steel. This furnace is now running on intermittent commercial production and the present operation shows attractive economies in power consumption.

Another use for electric heat in sheet mills is the electric roll heater. This was discussed briefly in last year's report. Electric heaters are now used in some twenty different plants rolling nickel, monel, full finished sheets, black sheets and tin plate.

In plants rolling nickel and monel metal the avoidance of the necessity of warming-up on iron is a great

benefit. One mill has operated single-turn, using the electric heaters daily to maintain the rolls in condition during the off period.

In plants rolling full finished sheets, the improved quality of the first turn production is important, as well as the increased quantity. Electric preheating has definitely proved its ability greatly to reduce the number of "seconds" produced on the first turn.

Two well established advantages in black sheet mills are the increased production and the ready adaptability of the stock to meet current orders. Marked increases in first turn production of salable product have been made without attendant increases in roll breakage. Mills find it advantageous to roll narrow iron late in the week, when the rolls are not in condition to roll full width sheets, rather than during the first turn. Decrease in scrap loss during the first turns represents a substantial economy.

In tin mills, the electric roll heater is proving a boon, greatly increasing the first turn tonnage and improving the practice. Here the decrease in scrap loss is a marked advantage and the improvement in quality and surface of first turn production are also a benefit.

The ability to preheat stationary rolls in racks prior to a mid-week change has proved of greater advantage than originally anticipated. Several mills are changing several sets of rolls each week and then proceeding immediately with regular production.

Electric roll heaters have proved sufficiently sturdy to warrant their classification as mill equipment and

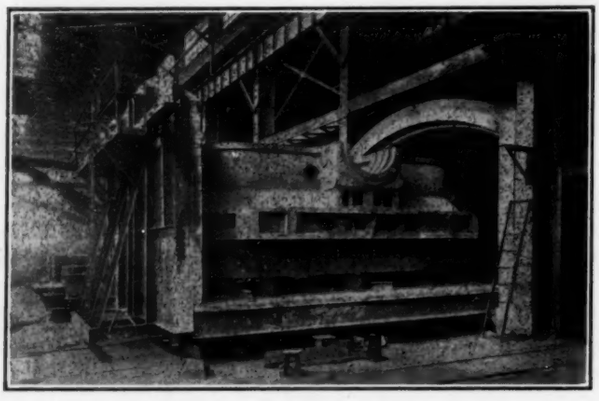


FIG. 2—Car Bottom Type Electric Furnace for Aging Large Iron Castings.

the heating elements have proved particularly serviceable. A number of improvements have been made during the past year to this end. Very little electrical trouble has been experienced.

Foundries

In the production of rough castings, heat is required in the following processes at the temperatures indicated:

1. Core baking .....450 - 700° F.
2. Sand - Drying .....450 - 700° F.
3. Pattern Heating ..... - 700° F.

Electricity has been successfully applied to all of the above processes, and some of these applications were described in our report last year. We believe it is unnecessary to devote further attention to them. Heating can be done satisfactorily by electricity, if conditions warrant the change from other methods.

Annealing Iron Castings

A large electric furnace which has been in use for three or four years, for aging large iron castings, varying in section to a considerable extent, is shown in Fig. 2. The furnace was originally installed when the requirements were for uniform temperature within 50° throughout the furnace and it was found that with a fuel-heated furnace there was a variation of more than 100°, due to the impossibility of controlling temperature in such a large furnace with combustion heating methods. The electric furnace is of the familiar car bottom type with the door mounted

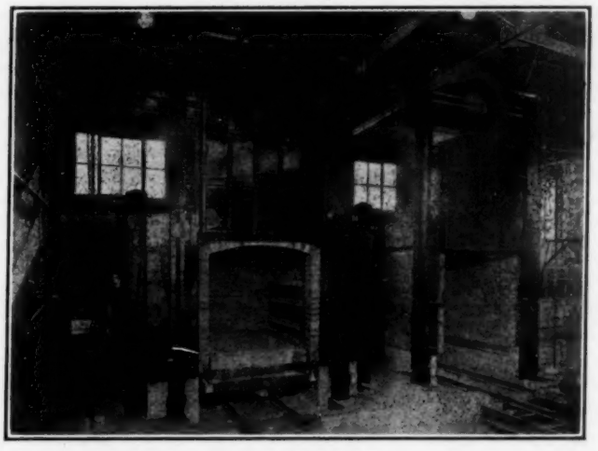


FIG. 3—Direct Heat Type Electric Furnace for Annealing Castings.

on one end. The furnace is 28 ft. deep, 16 ft. wide and about 8½ ft. high inside, with 720 kws. connected. Charges up to 50 tons are annealed in this furnace at 1000° F., and the temperature variation does not exceed 30°.

Annealing Steel Castings

Fig. 3 shows two furnaces used in an electric foundry for annealing castings, both steel and brass. These furnaces have been in use for the past two years, operating as high as 1700° F. 24 hours a day, and except for some not costly repairs on the doors and cars, the maintenance cost has been almost negligible.

These furnaces are typical of a number of installations in steel foundries throughout the country during the past two years. It is found that the product from these furnaces is of uniform high quality, and these results are obtained with less scale loss, and under much better working conditions. Such annealing work can be done without night attendance, thus getting the advantage of off-peak rates for power; and often the same furnace is used during the daytime for heat treating. Electric furnaces of this character are controlled automatically with respect to temperature, and, by means of the time switch, can be cut in and out of circuit at predetermined hours, which greatly simplifies night operation.

Heat Treating

After the rolling or casting processes outlined above, a surprising amount of iron and steel products undergo heat treating processes to give them

the physical properties necessary for their use. It is estimated by Prof. A. E. White of the University of Michigan, an authority on heat treating, that in 1924 two million tons out of thirty-five million tons of steel produced were heat treated. It is in this field that the greatest number of applications are found for electric heat.

Heat Treating Tools and Dies in the Electric Furnace

All metal working plants have occasion to heat-treat dies and miscellaneous tools used in the manufacturing of virtually all products. Until about three years ago, it was a general practice to use either gas or oil fired furnaces for the heat treatment of these tools and spoilage of the latter often occurred through inability to properly control the temperature, distribution of heat, and furnace atmosphere. Such furnaces produced much good work, but the factors beyond control caused a relatively high percentage of spoiled work, or only poorly treated tools.

During the past three years, tool furnaces have been perfected, ranging in size from a hearth about 8 in. wide x 16 in. deep, up to a hearth area of 3 ft. x 7 ft., suitable for large die blocks. The kw. rating of these furnaces ranges from 5 for small size to 80 for the largest. Fig. 4 is a typical installation which also shows the cylindrical type of furnace.

The hardening and tempering of steel tools require uniform heating to the proper temperature throughout the mass of the metal in order to get maximum hardness and strength, and any slight deviation in these conditions will prevent the best

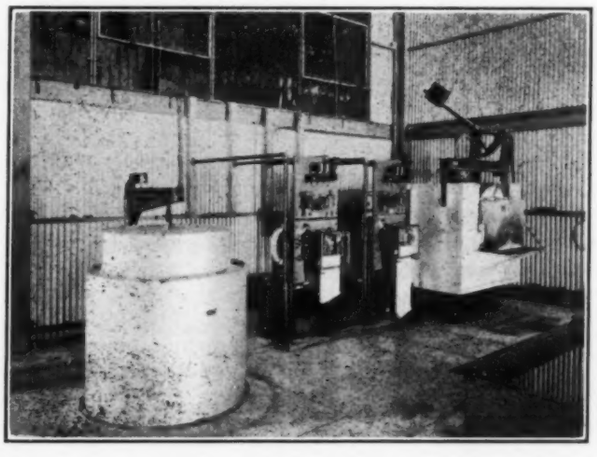


FIG. 4—Standard General Electric Direct Heat Vertical and Box Type Furnace used for Heat Treating Tools.

results, or may cause breakage, or cracking in the quenching. In the electric tool furnace, the units may be so distributed as to give perfectly uniform heat from front to back and the temperature is automatically controlled by instruments of precision, so that uniformly good results are obtained with an unskilled and indifferent class of labor.

A number of these furnaces have been in operation in one plant for almost four years, with no maintenance expense whatever, except occasional repairs to the hearth, and during that time not a single die or tool has been lost due to improper heat treatment. It was found that the standby operation of this furnace cost less than a fuel-fired furnace, considering energy costs alone, so that with the addition of the uniform and high quality of work obtained there can be no doubt of the advantages of the electric furnace for this purpose. However, it should be mentioned that the tendency is to give unwarranted consideration to the cost of fuel or electricity for heating operations. A careful analysis of costs of various steel parts has disclosed that the electric energy for heat treating costs, on the average, only ½ of 1% of the manufacturing cost of the part, whereas the improvement in these parts is equivalent to a high percentage, and this should be accredited to the electric furnace.

Metallurgy

Although the subject of metallurgy is beyond the scope of this report, the following definitions and brief discussion relative to some phases of heat treating are included here as a quick, though incomplete reference, so that some of the terms used in heat treating, and the names of the types of furnaces in use may become connected in the busy mind of the average steel mill electrical engineer. In making any decision as to what is involved, he should have some knowledge of the topics mentioned here. If he has this information he will be able to understand the language of his heat treating engineer. For complete understanding he must refer to textbooks, and the technical literature on the subject.

The International Association for testing materials defines steel as "Iron which is malleable at least in some one range of temperature and, in addition, is (a) cast into an initially malleable mass; (b) is capable of hardening greatly by sudden cooling; (c) is both so cast and so capable by hardening."

Cementite

Iron and carbon from a hard, brittle, crystalline compound, the composition of which is represented by the formula Fe3 C. The compound is referred to as iron carbide or cementite.

Graphite

Under certain conditions some of the carbon of iron carbon alloys is present in the form of graphite.

Alpha Iron

Solid iron is crystalline in structure, belonging to the cubic system. There are two distinct crystalline modifications of iron, which are distinguished from each other by the arrangement of the atoms within the crystals. These modifications are stable only in definite ranges of temperature.

At all temperatures up to 1652° F. the arrangement of the iron atoms is that of the body-centered lattice. This form of iron is called Alpha iron.

Gamma Iron

When pure iron is heated through 1652° F. a complete recrystalization occurs with the formation of new grains of a different crystalline modification known as Gamma Iron, which has a face-centered cubic lattice.

There are other allotropes of iron—much better understood by recent investigations, but their discussion belongs to the technical discussion of that subject.

Metallic Solid Solution

Many metals possess the ability to dissolve certain other elements in the solid state, forming solid solutions, which in many ways are analogous to ordinary liquid solutions.

Ferrite

Alpha iron is capable of holding in solid solution considerable amounts of various elements such as nickel, silicon, phosphorus. The maximum solubility of carbon in alpha iron, occurring 1335 degrees F. is less than 0.10 per cent of weight. This is believed to decrease as the temperature falls. The term "ferrite" is applied to solid solutions in which alpha iron is the solvent.

Austentite

Solid solutions in which gamma iron is the solvent are called "austentite." Gamma iron dissolves carbon to a great extent. The maximum solubility at 2066° F. is 1.70 per cent. This decreases with temperature to 0.90 per cent at 1337° F.

Pearlite

At 2066° F., austentite will hold 1.7 per cent carbon in solid solution. When austentite of this composition is cooled, cementite precipitates from the solution. With moderately slow cooling, the decomposition of austentite containing 0.90 per cent carbon results in the formation of a constituent in which ferrite and cementite occur as alternates. There lamella refracts light in a similar manner to the lines of a diffraction grating, giving the constituent a pearly appearance, from which it has received the name pearlite.

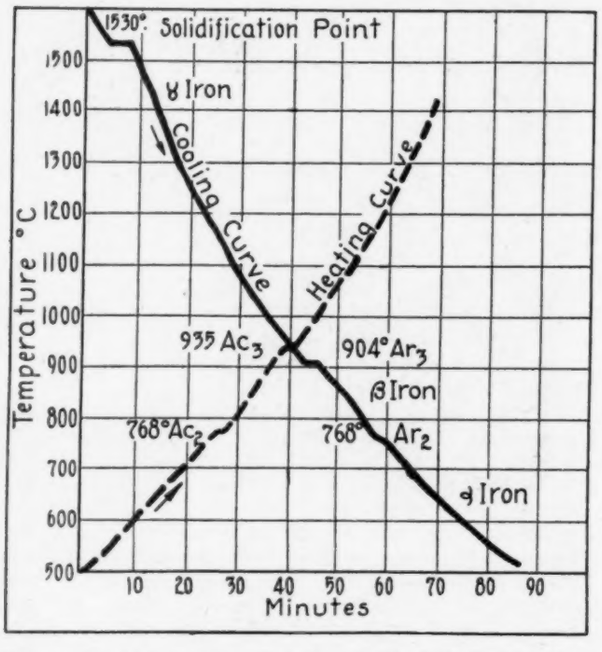


FIG. 5—Typical Curves Showing Critical Points in Iron.

Critical Points

The temperature at which alpha iron forms from gamma iron on cooling is lowered by the presence of carbon in solid solution in the gamma iron, that is, in austentite. The formation of ferrite forms the solid solution. Austentite is analogous to the precipitation of a salt from its solution in water.

When a steel containing more than 0.90 per cent carbon is cooled from a temperature at which it is austentite, cementite begins to deposit. Since cementite contains 6.67 per cent carbon its precipitation causes a lowering of the carbon content of the austentite. This lowers the temperature at which cementite precipitates, and the cooling of the steel results in a progressive precipitation of cementite and a progressive decrease in the carbon content of the austentite.

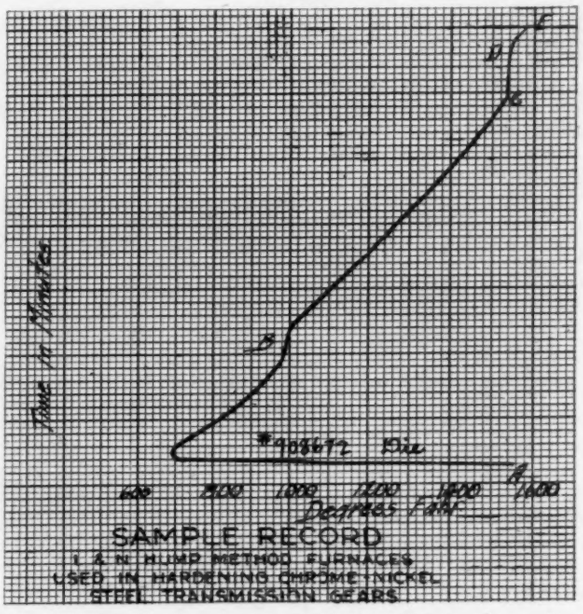


FIG. 6—Sample Record of "Hump Method" used in Hardening Steel.

The phase changes which occur on cooling, as described above are reversed on heating.

The critical points or phase changes liberate heat when they take phase on cooling, and absorb heat on heating. These critical points can be observed by placing a thermo-electric pyrometer in molten iron and plotting the temperatures against the time of cooling. It will be found that at these critical points, certain "breaks" will occur at which the steel will remain at the same temperature for a noticeable length of time. This shows that at these points there is an evolution of heat within the steel due to a rearrangement of the grain structure. A sample of such a curve is shown in Fig. 5.

At the temperature range between critical points, the steel has a certain definite crystalline structure which may be preserved at working temperatures by rapidly cooling or quenching. In order that the steel may have a uniform structure throughout, it must be uniformly heated. This requires a uniform and rather slow application of heat so that there will not be too great a difference in temperature between different points of the piece. Otherwise, outside point may have passed the desired range before the middle of the piece had yet entered this temperature.

While the composition of the grains is determined by the temperature to which it has been

heated, their size, which is also very important to the properties of the steel, is affected by other factors. These are the rate of cooling through the critical points and the length of time which it is held above the critical temperature, allowing growth of the crystals. The grain structure is also affected by mechanical working.

It will be apparent that the electric furnace possesses an advantage in its accurate control of temperature, making it possible for the work to be brought to the correct temperature and held there for only the required length of time. Before the advent of the electric furnace, with its accurate temperature indicating devices, it was necessary in some heating processes to determine by its color when the piece had reached the correct temperature. Although it is true that the color bears a definite relation to the temperature, this method is subject to the "personal equation" and leads to extremely variable results. With the electric furnace, the correct temperature and heating cycle for a given piece can be determined, and the results duplicated even with ordinary unskilled labor.

A very interesting process which makes use of the indication of "critical points" on the temperature chart, is the "Hump Method" developed by the Leeds and Northrup Company. The method consists simply in placing the piece to be heated in an electric furnace having a recording pyrometer. The temperature follows a curve, such as shown in Fig. 6.

The work is first charged into the furnace which is at a temperature of 1400° F., the current being turned off. The work absorbs the furnace heat causing temperature to drop to about 700° F. This followed by a slight recovery to B where the break in the curve indicates that the work and the furnace have reached the same temperature At this point the current is turned on and the furnace and contents are brought up to temperature at the same time. The break occurring at point C indicates the critical point. The work is then kept in the furnace only the correct duration of time, which has been previously determined, and is then quenched in proper solution in a conveniently located tank.

This method is used extensively for the hardening of various tools, such as punches and dies. For this class of work, the "Hump Method" is said to closely approximate the ideal conditions. A special design of furnace is necessary to permit the heat absorption at the critical point to be recorded. This may restrict its application to certain classes of work in which it is possible to place the thermocouple in such position as to record the temperature accurately. It will be seen that although this method is applicable to either large or small charges, it is not suitable for a charge consisting of pieces of varying size or shape, as each would reach its critical point or "hump" at a different time.

Returning now to the discussion of the elements of heat treating, we have the following definition by Bullens of heat treatment:

"Heat treatment in general consists in changing or regulating the structure of the steel by various methods of heating and cooling. By the term "structure" is meant (1) the metallagraphic constituents among which are those just described; (2) the size of the grain; (3) the net works." The processes of heat treatment may be classified as follows: (1) Annealing, (2) Hardening, (3) Tempering and Toughening, (4) Case carburizing, or simply carbonizing.

Annealing

Annealing in its commercial application may have for its purpose any or all of the following aims:

(1) To soften the steel and thus put it in condition for machining, or to meet certain physical specifications.

(2) To relieve any internal stresses or strains caused by previous hardening or working.

(3) To obtain the maximum refinement of the grain in combination with much ductility.

Fundamentally, annealing consists of two well-defined phases, the heating phase and the cooling phase. Both must receive careful consideration by the metallurgist in determining the procedure to be used in handling any given steel for a certain given result. In particular, the cooling may be at a very slow, uniform rate, as in the furnace, or the material may be allowed to cool in the air.

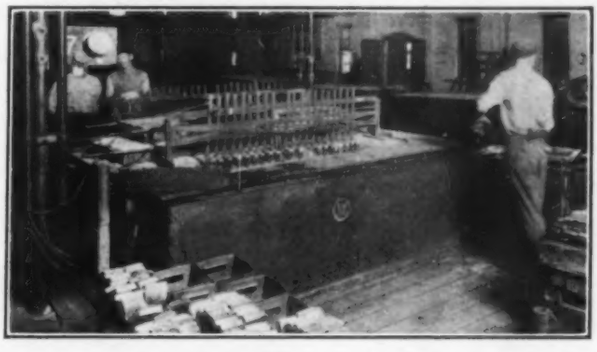


FIG. 7—Westinghouse Lead Bath for Heat Treating Axes.

Hardening

Fundamentally, the operating of hardening steel consists of heating it above the critical temperature and cooling it rapidly. The main difference between hardening and annealing has to do with the rate of cooling through the critical ranges.

Tempering

When a piece of carbon tool steel is heated to a red heat and quenched in water; that is, hardened, the steel becomes hard and brittle and is held in such a state of stress that its use, except in a few particular cases, would be highly inadvisable. This hardening operation has arrested a transition in the grain structure. The application of heat will now accomplish two results: (1) it will relieve the hardening strains; (2) it will permit the transition in grain structure to proceed. This process of reheating after hardening is called tempering.

Toughening

As the reheating or drawing temperature is increased still further beyond the tempering range, another stage in the change of the grain structure commences. Without going into the technical description of this change in structure, it may be noted that this change is in the direction of a somewhat softer and more tenacious material. In a general way the toughening range lies approximately be-

tween 750° and 1250° F. The exact temperature required for any particular steel depends upon its chemical composition, degree of hardening, size of the work, etc. In hardening steel there is maximum tensile strength with minimum ductility; and at the other extreme, as in fully annealed steel, there will be minimum tensile strength with maximum ductility. When one is up the other must be down.

As an example of a successful application of heat treating tool steel, Fig. 7 shows the electrically heated lead bath. This lead bath operates at 1480° F. and is controlled by a thermo-couple in a nichrome tube immersed in the lead bath.

The lead bath is maintained within 10° F. of the desired temperature by means of a controlling recording pyrometer functioning through a motor-operated relay, and a contactor which turns the power on and off of the furnace.

The electrical input entering the furnace is 62 kw. single phase, 220 volts. As can be seen, the furnace shell consists of boiler plate; next to this is a course of thermal insulating brick, and then the thermal brick which supports a nichrome vessel 60 in. long, 12 in. wide at top and 14¾ in. deep. The vessel is designed with sloped walls and is supported by a 3-inch flange on the masonry heating chamber wall on which are supported No. 1 B. and S. gage heat-resisting wire formed into S bend coils 58½ inches long between return bends. These coils are placed on the side walls and bottom of furnace chamber.

This lead bath is for treating axes varying in size from 6½ pounds down to 3½ pounds—both single and double bits.

220—6½-pound sizes per hour have been hardened by heating 2½ pounds of the cutting edge up to 1460° F. and quenching in brine.

Lead baths of exactly similar physical dimensions are used for drawing the axes operating at 650° F. or lower. Three such furnaces draw the product of four of the high temperature hardening baths.

The Kelly Axe and Tool Company has installed fourteen of these furnaces in its plant at Charleston, W. Va. and seven more of similar types, but of slightly different inputs and physical dimensions in its small heat-treating room. The quality of product that these lead baths are producing has never been excelled in the long history of this successful tool company and the rejections, due to factory heat-treating, have been entirely eliminated.

The striking point here in addition to the above facts is that the operating and maintenance costs of these furnaces, even in the natural gas belt, has been lower than the old gas-fired lead baths, or air heat-treating furnaces.

Case Carburizing

The object of case carburizing, carbonizing or case hardening is the production of a hard wearing surface on low carbon steel, at the same time retaining the toughness of the core of the metal. The process may be roughly divided into two distinct operations: first, the carbonizing or impregnation of the surface by which the carbon content is sufficiently raised to give a very hard surface; second, suitable heat treatment which shall develop the properties of both case and core. Steel is case hardened in general by being packed in material containing carbon. The charge is heated to the required temperature (about 1600° F.) at which the steel absorbs carbon from the surrounding packing material, and is held at that temperature a sufficient time to secure the desired penetration of carbon. Many operators use 1800° F. which seems to be too high for this work. Better results can be had at the lower temperature suggested above, with perhaps a little longer time of heating. From the experience of a large manufacturer with electric furnaces on carburizing work, it is believed that the electric furnace can make a better showing on this class of

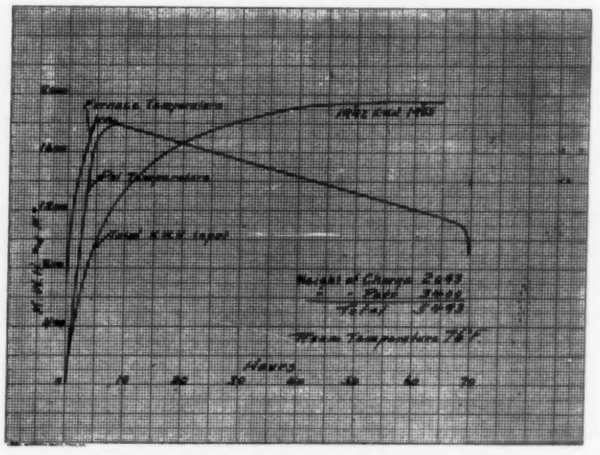


FIG. 8—Typical Heating Cycle for Annealing Malleable Castings.

work than any other class of heat treatment. The thickness of case hardened surface depends on the temperature and time of material in the furnace. With a uniform temperature in the furnace chamber and the temperature controlled automatically, the heating time is reduced. Materials carburized in an electric furnace are absolutely uniform, whether you compare pieces from different boxes in the same charge, or pieces from different charges.

Malleableizing.

This process consists essentially of a long cycle of heat at 1600° F. and then a very gradual cooling. Malleableizing is a long process, sometimes requiring two weeks to obtain the best results. Cooling is often held down to three degrees per hour. Fig. 8, shows a typical heating cycle annealing malleable castings in an electric furnace.

These definitions refer to the carbon steels. There is also an ever-growing family of alloy steels such as the nickel-chromium, vanadium, manganese, molybdenum, tungsten, silicon, uranium combinations including high speed and tool steel, which are all heat-treated under analogous conditions to those employed in the carbon alloy group. Temperatures and methods of operation are different, but all require heat treatment at various stages of their development.

Heat Treating of Non-Ferrous Metals

Non-ferrous, as well as ferrous metals may have their grain structure changed by heating. Heat-treating of non-ferrous metals, however, is usually an annealing operation. A significant fact is that non-ferrous metals, after being heated to anneal may be cooled by quenching in water. Bright annealing,

that is, without oxidation, is done in a furnace with a sealed chamber, as illustrated in Fig. 9.

Bright annealing requires that the atmosphere in the furnace be neutral or reducing. Such an atmosphere is somewhat difficult to maintain on account of air leakage and the entrance of air when the doors are opened for charging and discharging. A small quantity of carbon, or oil is often placed in the furnace to satisfy the oxygen of the air in order to produce a neutral atmosphere. Carbon monoxide and ammonium sulphite gas are sometimes used, but their presence in large quantities is injurious to the nickel chromium resistors or heating elements

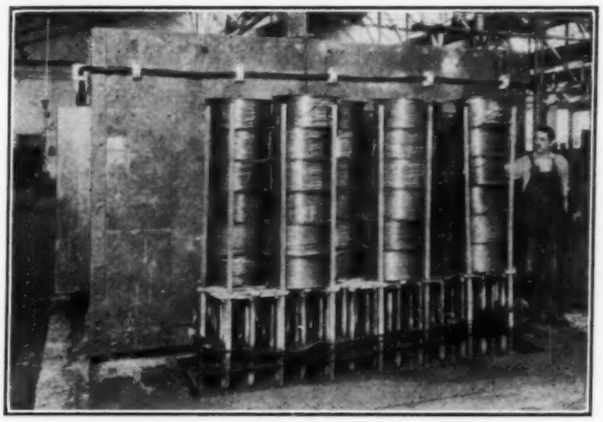


FIG. 9—Electric Furnace for Bright Annealing Copper Wire.
The charge of 10,000 lbs. is lowered and after the heating chamber is pushed over it is raised to position.

It is possible, of course, to operate fuel-fired furnaces so as to have a neutral and reducing atmosphere. It requires, however, an abnormal consumption of fuel, and there is a very distinct tendency on the part of furnace operators to use more air than necessary and thus have an oxidized atmosphere in the furnace. This results in severe scaling of the material heated, and if the material has a high value, its loss is an important item of cost. The resultant cost of cleaning the product also is usually higher.

Equipment for Heat Treating

Having outlined the requirements of the furnaces for various heat-treating processes, let us now discuss the factors to be considered in the selection of the proper furnace for the job, without regard to whether it is to be electric or fuel-fired The following is a list of the requirements of the furnace:

1. It should be of such nature, and so designed as to bring the work uniformly to the desired temperature within the limits of accuracy required by the process.
2. The temperature should be accurately and automatically controlled.
3. It should be the most economical equipment for the job, taking into account all of the factors which affect the "total overall cost of production."
4. It should not require highly skilled operators, and should be capable of producing the desired results without constant attendance and adjustment.
5. It should be of such construction that it will stand up under the treatment to be expected in steel mill service.

Control of the temperature of the furnace chamber is essential for best results, but the temperature must be also uniformly applied to the work. This requires attention to the shape of the chamber and the method of loading. Referring to the chart, Fig. 10, the shaded portions are those to which the heat penetrates last. It is apparent that the best condition is that in which heat is applied to the greatest surface and mass of the charge. The application of heat to the bottom is often neglected and leads to non-uniform heating. This can be solved by raising the charge off the floor as shown in D. H. and O, and by applying heat to the bottom of the charge. Both fuel and electric furnaces use bottom heat, but furnace engineers generally agree that it is preferable also to have a heavy charge raised off the floor.

In comparing electric and fuel-fired furnaces in this respect it must be realized that with suitable equipment and proper attention, the fuel-fired furnace, as well as the electric furnace can be made to maintain a uniform temperature, as indicated by the temperature chart. The purpose of the furnace, however, is to produce a uniform product, and not uniform temperature charts, so that proper attention must be given to the design in order to uniformly apply the heat to the product.

A perfectly uniform temperature chart shows that the temperature is uniform at the point in the furnace chamber at which the temperature indicating device is located. It does not mean, however, that the temperature throughout the furnace is uniform, but that it may vary widely. To secure uniform application of heat, and uniform temperatures requires careful attention to the design and method of loading, whether the furnace be gas, oil, or electric. It must not be assumed that a furnace will

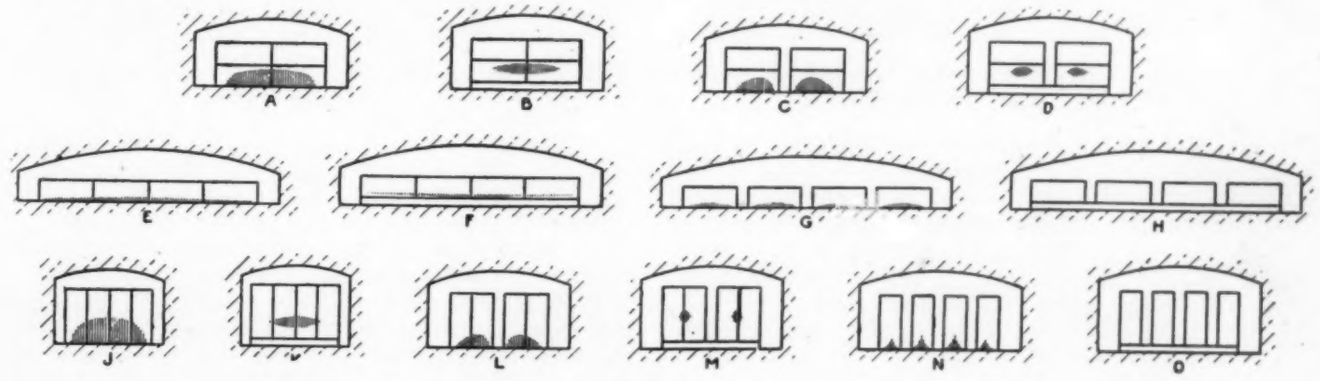


FIG. 10

give better results merely because it is electrically heated.

The electric furnace differs from fuel-fired in the manner of the application of heat. Most of the heat transfer in the electric furnace is by radiation; the remainder is by convection, which is depended upon to a certain extent to apply heat to those surfaces which are not reached by radiation from heating

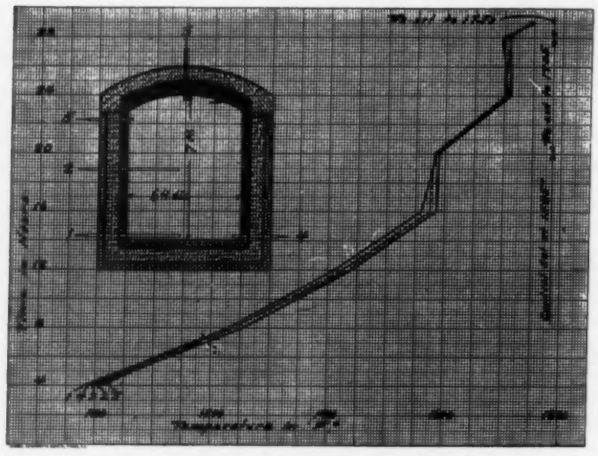


FIG. 11—Heat Distribution in a Vertical Electric Furnace.

	Temperature Readings Deg. F.							
	Thermocouples.					Average	% Variation	
Time	No. 1	No. 2	No. 3	No. 4	No. 5	Temp.	Above	Below
11:30	77	77	77	77	77	77	0	0
3:30	981	999	990	986	1013	993	2.07	2.31
7:30	1238	1254	1240	1231	1237	1237	1.5	.45
11:30	1451	1441	1429	1411	1436	1429	1.0	1.3
3:30	1576	1587	1575	1560	1587	1580	.46	1.3
7:30	1580	1589	1584	1584	1585	1584	.35	.23
11:30	1702	1713	1706	1706	1702	1706	.43	.21
3:30	1710	1710	1701	1697	1701	1704	.64	.43
4:30	1742	1742	1746	1746	1751	1746	.31	.21

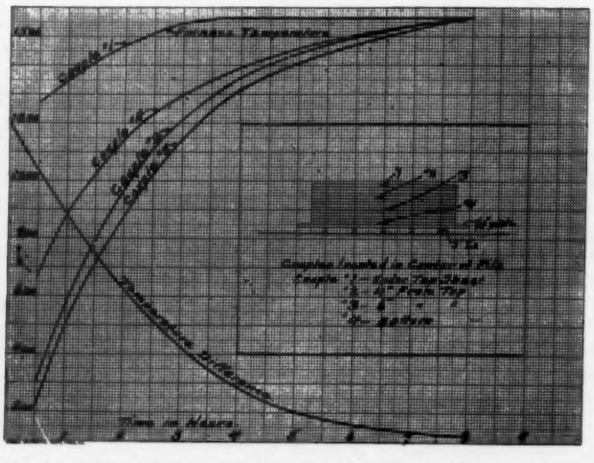


FIG. 12—Curves Showing Temperature of a Pile of Sheets 25" by 20" by 9" high Heated in Electric Furnace.

elements and walls. By proper distribution of heating elements, however, practically a uniform temperature distribution can be obtained, and the transfer by convection reduced to a very small quantity.

With the fuel-fired furnace, a large part of the heat is transferred by direct convection from the hot gases circulating about the charge, and some by radiation from walls and burners. The dependence placed on circulation of the gases leads to non-uniform temperature distribution. Owing to the nature of the gas, or oil-fired furnace, large sources of heat are concentrated at a few points; whereas, in the electric furnace, the heating elements can be distributed almost uniformly over the walls, and if desirable, on the top and bottom.

In a combustion furnace where the source of heat is the flame, it is almost impossible to maintain a uniform temperature from front to back, and from

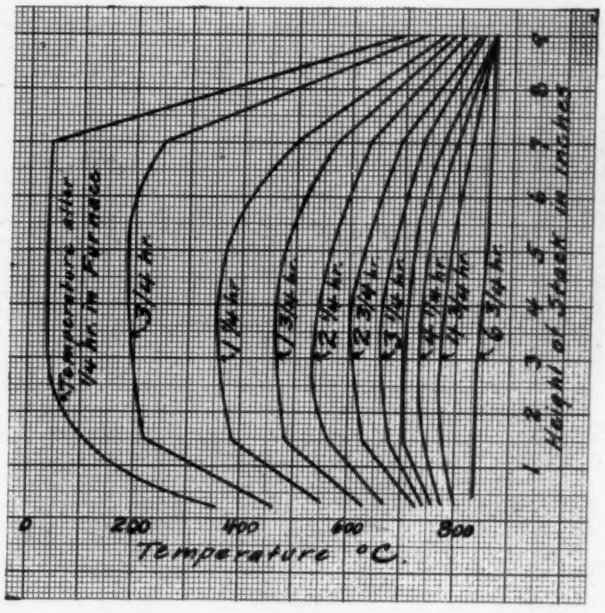


FIG. 13—Temperature Distribution in a Stack of Sheets Heat Treated in Electric Furnace.

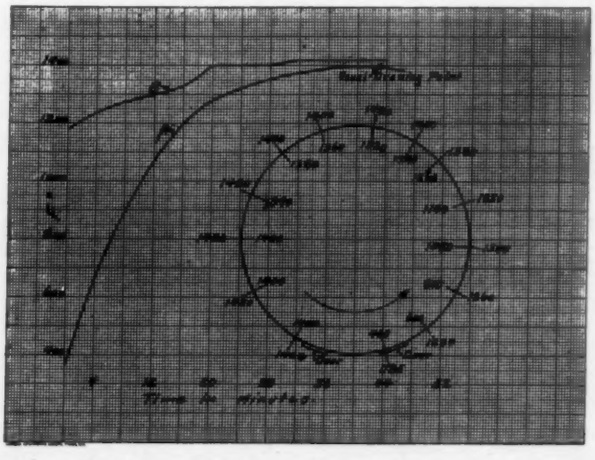


FIG. 14—Rate of Heating of a gear in a Rotary Type Electric Furnace.

top to bottom. The higher the temperature to which the piece is to be heated, the easier it is to obtain a uniform temperature. Hence, good results can be obtained at 2300° to 2500° F. At temperatures below 1800° F. hot spots and cold spots will be found in all combustion furnaces.

In continuous or rotary type furnaces, where the chamber is relatively long, electric heat is especially desirable because of the ability to distribute the source of heat over the length of the furnace. Often,

in such furnaces, the work is subjected to varying temperatures, as it progresses through the furnace. The electric furnace can be divided into zones and the temperature of each zone adjusted to suit requirements. A description of such a furnace is included further on in the report.

Figure 11 illustrates the uniform heat distribution obtained in an electric furnace. The curves show the temperature indicated by the thermo-couples numbered 1, 2, 3, 4, and 5 located at various points in the furnace chamber. It will be noted that the temperature variation when the furnace is at operating temperature is .31% above and .21% below the instrument setting. This also is a fairly large furnace, being 6 ft. in width. It should be borne in mind, however, that these curves were taken on an empty furnace.

Figure 12 shows the temperatures measured by thermo-couples in a stack of sheets heated in an electric furnace. The thermo-couples are in the center of the sheets and at the distances from the bottom, as shown. During the first part of the cycle, there is naturally a large difference between the top and center of the stack, but the temperature becomes practically uniform after 8 hours.

The curves in Fig. 13 show the temperature distribution at various times in the cycle. Temperature is plotted on the horizontal scale and heights of the thermo-couple on the vertical scale. The temperatures curve is practically straight after 6¼ hours, and after a brief soaking period the temperature would be practically uniform.

Figure 14 shows the rate of heating of a gear in a rotary type electric furnace as the gear progresses through the furnace. Curve A shows a temperature in the furnace at a point 9 in. above the gear, and Curve B, the temperature measured by a couple inside the gear. There is, of course, a large temperature difference during the first part of the cycle, but at the higher temperatures where the rate of heating and temperature control are especially important, the temperature difference is very small.

Fuel-fired furnaces of the muffle type have better temperature distribution than those in which the combustion takes place in the same chamber with the charge.

Muffles will eventually leak out, but due to cost of replacing, will be used for some time after leak starts. A leaky muffle will not maintain any better temperature uniformity than an open fired furnace. Muffles reduce the heating capacity as compared to open fired furnaces. The amount the capacity is reduced depends on the heat conductivity of the muffle material and the area of the muffle.

Another point which should be mentioned is the rate of application of heat. Heat must be applied slowly in order that the outer portions of the work may not be at temperatures too much greater than those at the middle. This condition is necessary in order to prevent stresses in the material which may in some cases cause serious distortion. Rate of heat input should, therefore, receive consideration in selecting a furnace.

The comparison of furnaces from the consideration of economy requires that all factors entering into the cost of production be given due thought. It is unfair to the electric furnace to compare it with other types on the basis of energy cost, alone. The most economical method of heating is that which reduces the total cost of a satisfactory product, and often the lowest total cost follows the more expensive method of heating.

Elements of total cost of product which are affected by the heat treating furnace are:

1. Labor.
2. Loss due to rejections.
3. Cost of subsequent operations.
4. Handling of material.
5. Cost of auxiliary equipment.
6. Quality of product.
7. Intangible effects, such as working conditions in furnace rooms.
8. Floor space required, including space for fuel storage tanks, pumping and blowing equipment.

Under the cost of auxiliary equipment, there should be figured the cost of boxes used in such processes as carbonizing or annealing. These boxes last much longer when used in electric furnaces because they are not subjected to the action of impinging flames and hot gases. Manufacturers of high grade alloy appreciate this, as they will guarantee 50% longer life for use in an electric furnace than in a combustion furnace.

In some cases such containers can be dispensed with entirely with the electric furnace. When the boxes can be dispensed with, or even decreased in size, there results a saving in heat which is wasted when the boxes are allowed to cool. One such case is the annealing of sheets in an elevator type of furnace.

A word of warning is not out of place in connection with such elements in cost of product as the cost of handling. It is not fair to compare a modern electric furnace, and up-to-date handling equipment with an old wornout fuel furnace, and antiquated auxiliary equipment. However, it is a fact that electric furnaces are capable of taking advantage of labor-saving and automatic devices with low priced labor. The furnace, itself, is automatic, in requiring no attention, and it can readily be used on definite time cycles in connection with automatic, or semi-automatic equipment.

It has been stated that uniform temperatures can be maintained with the fuel furnace, as well as with the electric. This, however, in the case of the fuel furnace, requires a skilled operator in constant attendance. Even a skilled operator, or automatic control of fuel-fired furnaces cannot anticipate such things as a drop in gas pressure, or a change in quality of fuel and atmospheric changes which affect the temperature and conditions in the fuel furnace. The electric furnace is entirely automatic in its control of the energy input to the furnace and one kilowatt contains 3412 Btu., regardless of room temperature or outside atmospheric conditions.

In the electric furnace the temperature gradient between the source of heat and furnace chamber is comparatively low and it is not difficult to obtain refractory materials to give an indefinite life at these temperatures. In combustion furnaces the high flame temperature and the action of impinging flame on the refractory will give, in comparison, a shorter life. With a big temperature difference between combustion chamber and furnace chamber, unequal expansion also will shorten the life of the

furnace walls. Therefore, it should be apparent that the upkeep on combustion furnaces will be much greater than on electric furnaces. The heating units in an electric furnace that is properly designed should give a life of from 3 to 5 years. The present industrial furnace has not been in service long enough to really determine the life of the heating units. Furnaces installed for four and five years have the original heating units still operating.

It is generally recognized that the electric furnace is more efficient in the utilization of heat because of its lower radiation losses. It has been stated, however, that more insulation is a necessary evil with the electric furnace in order to make it compare in economy with the fuel-fired furnace. This is true, but it is also true that a certain amount of temperature loss through the walls must be allowed in a fuel-fired unit. This is because of the high local temperatures which would be destructive to refractories if this loss were not provided for. The electric furnace, therefore, makes possible better working conditions by decreasing the quantity of heat which is dissipated in the furnace room.

Installations

The descriptions and data of recent electrical installations were submitted to show what has been done during the past year and what may be expected in the future. It will be noted that the electric furnace has progressed from the small, laboratory equipment to large production types used for turning out large tonnages with laboratory accuracy.

We have not attempted to cover the thousand and one miscellaneous applications of electric heat in steel mills which can be made with standard equipment. As an example, we cite the case of one steel mill which had trouble with some expensive, high grade rolled strips rusting in the warehouse. On Sundays and during shut-down periods it was necessary to keep steam up in the boilers to keep the warehouse warm and to prevent condensation of moisture. Installation of space heaters effected a large saving in cost of operation.

Conclusion

In conclusion, the committee wishes to emphasize the fact that all factors contributing to or affecting the "total overall cost of production" should be considered in comparing various types of furnaces, bearing in mind the small proportion which the cost of energy for heat treating bears in the complete product.

In the interest of future developments it is recommended that accurate cost records be kept of both electric and fuel-fired furnaces. Such data, if available, would make possible a settlement on a more intelligent basis of the question of the proper type of furnace. All processes requiring the application of heat should be carefully analyzed by steel mill engineers to learn if lower overall cost of production might not result from the application of electric heat.

A large part of this job in the steel plant will fall to the electrical engineer just as did the replacing of antiquated steam drives by electric motors. The industry looks to the electrical man for the improvement of product and the reduction of costs by the use of electric heating.

The selection of equipment for heating processes, in the large plants, at least, is in the hands of combustion engineers. These engineers realize that in many cases economies can be effected by the use of electric heat. Their co-operation, and the benefit of their wide experience in the application of heating equipment, should be secured in the electrification of heating processes.

*Electric Melting Furnaces**

By J. A. SEEDE†

ALTHOUGH the arc and induction types of electric furnaces for melting metal started on an even basis in occupying the attention of inventors and builders over twenty-five years ago the superiority of the arc furnace for the average user was soon indicated by its ability to make heats of different metals on an intermittent cycle and gave it a pre-eminence which caused its widespread use. This, as we all know, has resulted in its occupying a well established position in the iron and steel industries. In 1904, two 4 ton, two electrode, single phase Heroult furnaces were sold in this country, one to the Firth-Sterling Steel Company and the other to the Halcomb Steel Company. At first regarded more as laboratory instruments than commercial devices, their inherent qualities soon demonstrated their fitness for an important place in the manufacture of fine steels, and five years later, a 15-ton furnace of the same type, except for three phase operation, was put in operation at the Illinois Steel Company, South Chicago, Illinois.

From that time its commercial growth was fairly rapid, an especially popular type being the 6-ton Heroult, furnaces of this capacity being popular today under various names. A comparison of the electrical capacities of these furnaces in 1910 and 1925, indicates the progress in one line of development.

Tons	1910	1925
1	225 KW.	600 KW.
2	450 KW.	1200 KW.
3	600 KW.	1600 KW.
6	900 KW.	2200 KW.

The cause for this increase in electrical capacity was obviously the desire to increase production, other changes with the same idea in mind being increased voltage, faster charging, preheating of charge, etc., as covered by the 1924 report of this Committee.

*To be presented at Twentieth Annual Convention, September 14th to 19th, 1925.

†Industrial Engineering Dept., General Electric Co., Schenectady, N. Y.

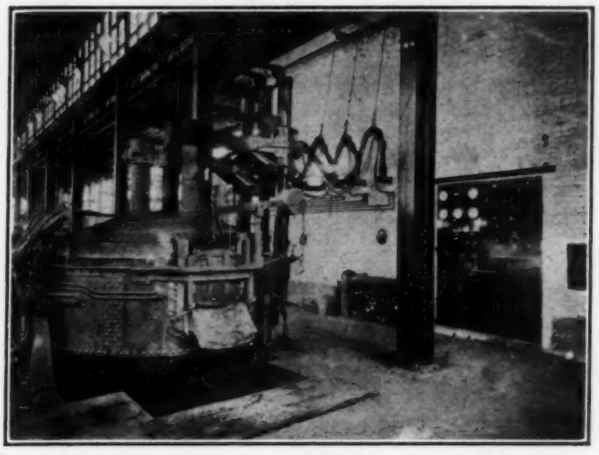


FIG. 1—3-Ton Pittsburgh Furnace Company Arc Furnace.

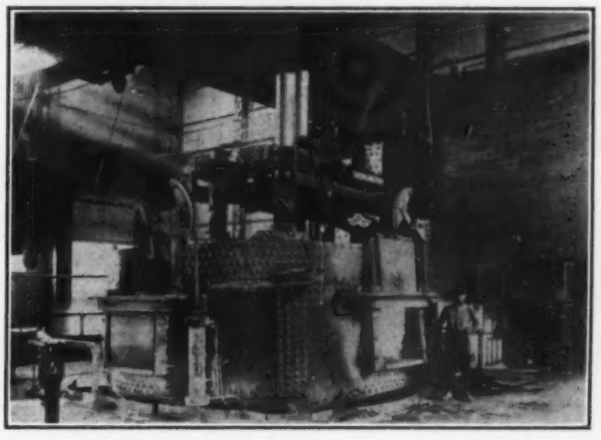


FIG. 2—25-Ton 3900 KVA 3-Phase Heroult Furnace.

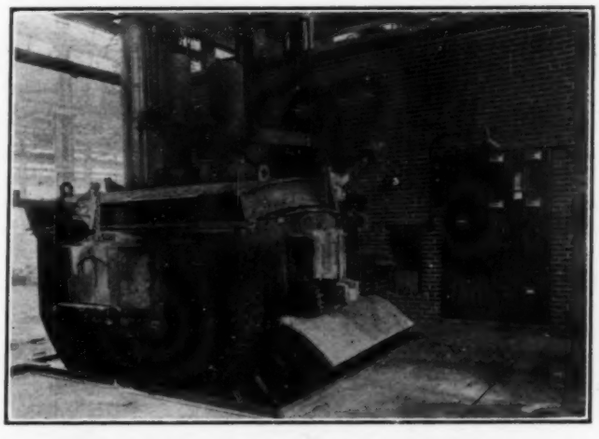


FIG. 3—3-Ton Greaves-Etchells Arc Furnace.

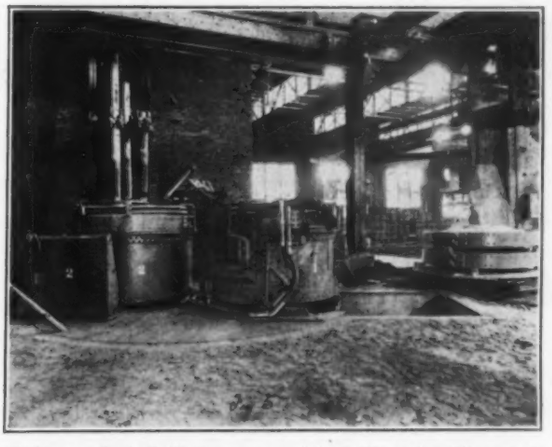


FIG. 4—Swindell Furnace with 2 Hearths Mounted on Turn Table.

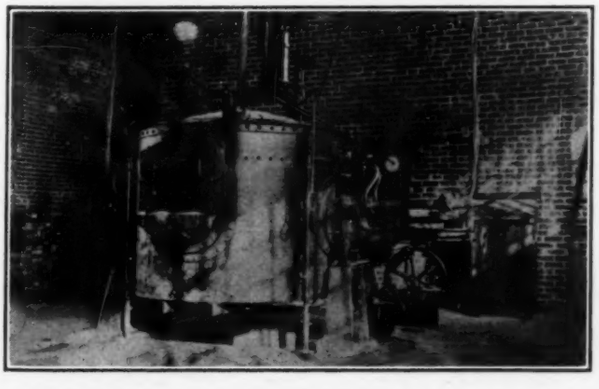


FIG. 5—One-Ton Rennerfelt Arc Furnace.

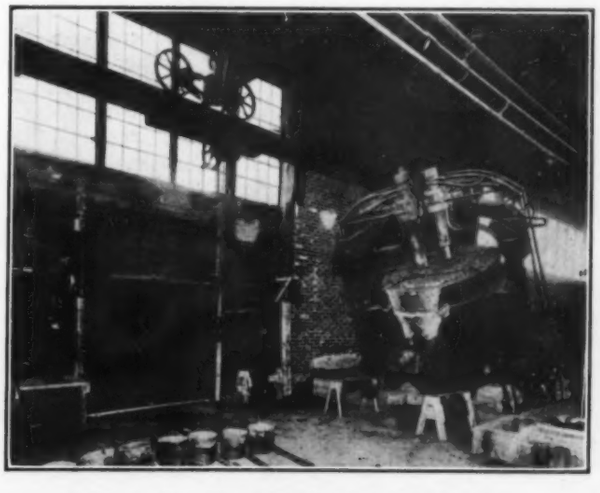


FIG. 6—One-Ton Booth-Hall Arc Furnace.

In order to obtain a clear idea of this development, a brief review of what has happened since the early Heroult and Girod furnaces is necessary. Any furnace for melting holds the molten metal in a hearth made of acid or basic refractory material, which either does or does not carry current. Accordingly, these hearths are broadly divided into conducting and non-conducting types.

Any furnace in which the current passes through the bottom, belongs to the conducting hearth type, and among them, following the Girod furnace may be listed the Gronwall-Dixon, Snyder, Wile, Nathusius, Greaves-Etchells, Moore, etc. In polyphase types, the low voltage transformer windings were connected either 3-wire two phase, neutral to furnace hearth, or modified Y connection of the Greaves-Etchells furnace where the short leg of the Y is connected to the hearth.

Disregarding the induction furnaces for the moment, which are all of the non-conducting hearth types, the Heroult type, one of the earliest of the non-conducting hearth types, still continues to occupy an important position. This type of furnace includes the Heroult, Webb, Booth, Swindell, VomBaur, etc. Both the Girod and Heroult furnaces cover the type of furnace where the current arcs from the electrode to the metal, but there is another type of non-conducting hearth arc furnace in which the current arcs between electrodes above the metal. The first furnace of this type was the Stassano, which had a very limited use in this country, which was later followed by the Rennerfelt, which had considerable success in capacities up to 3 tons, and the Repelarc, the latter in small units. About 1909 Mr. C. A. Weeks built a single phase furnace for melting non-ferrous metals and alloys which was somewhat similar to the Booth and Detroit, furnaces now in successful use for melting brass and bronze. This furnace was considerably larger than required for the average plant and commercial development waited until H. A. Gillett began his experimental work at Ithaca. The 100 KW. 250 lb. Detroit furnace has been especially successful in this field and a considerable number are now in successful use.

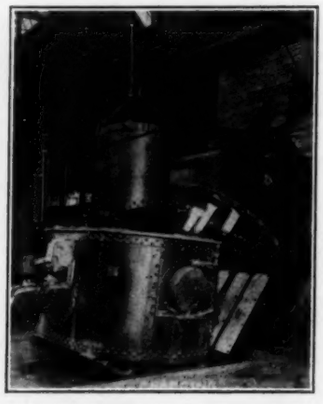


FIG. 7—3-Phase Arc Furnace with Lifting Roof and Charging Pocket.

100 KW. for a 250 lb. furnace indicates the tremendous change that has taken place in the last 15 years when 225 KW. was the normal rating for a 1 ton steel furnace. The rapid melting obtained is indicated by a guarantee of molten metal 20 minutes after power is turned on.

Two-voltage operation for steel melting furnaces is now practically universal, continued investigation indicating that there need be no deleterious effect on the product and a decided saving in power and electrode consumption, and increase in production.

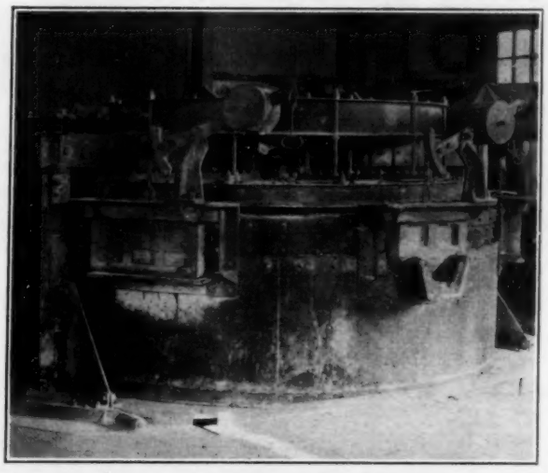


FIG. 8—2-Ton General Electric Single Phase Induction Furnace.

The differences between various furnace equipments are confined to range in voltage between electrodes, power available at various voltages, means for varying the voltage, amount of reactance, its location and control and similar matters, together with mechanical and operating details.

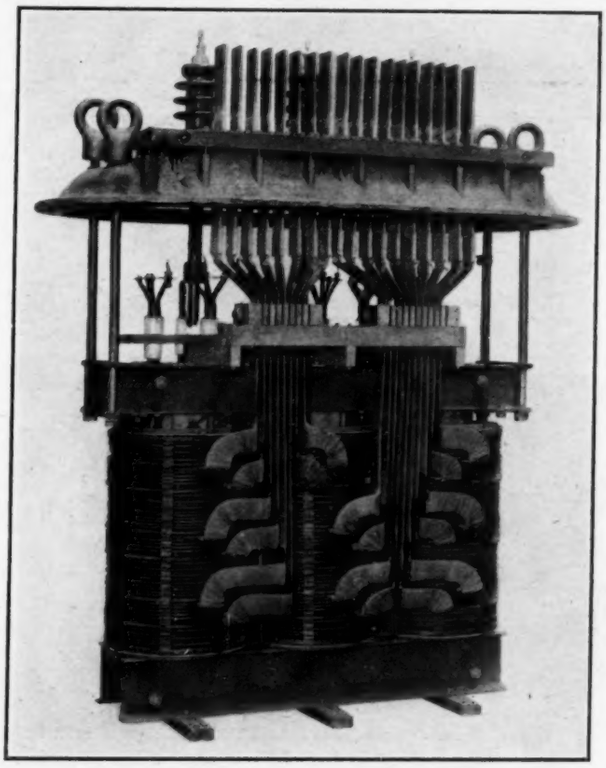


FIG. 9—1500 KVA 3-Phase Arc Furnace Transformer.

In addition to the increase in capacity of electrical apparatus, other changes have taken place, briefly indicated as follows:

Transformers

For many years, three single phase transformers were specified for a 3 phase furnace, probably under the belief that if one transformer failed, it could be cut out and the heat finished with two transformers operating open delta. Because of difficulty in disconnecting heavy low voltage conductors, this is hardly possible, and with increased knowledge of arc furnace operation and steadily increasing reliability of transformer construction, together with

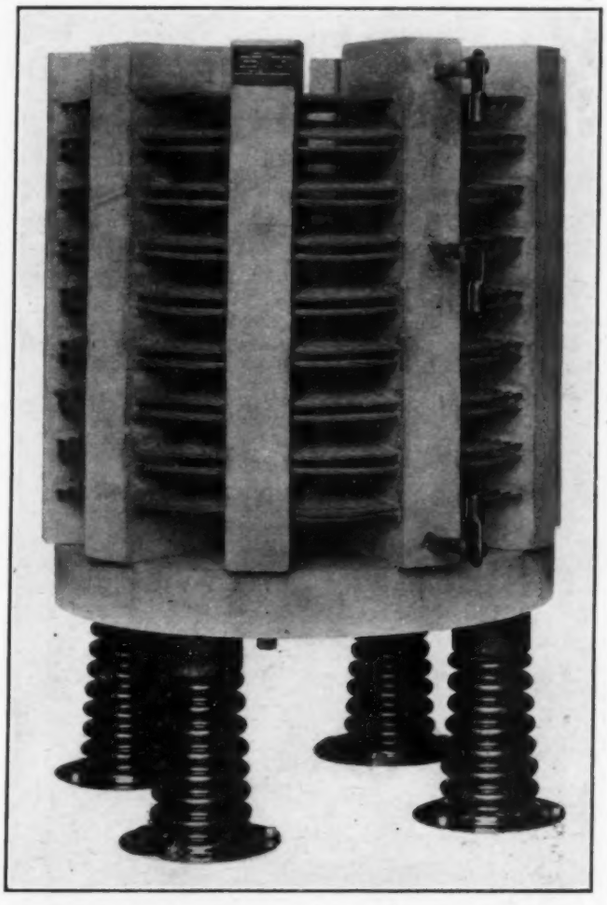


FIG. 10—Air Core Reactor for Arc Furnace Control.

better protective and controlling apparatus, thoroughly successful operation is being obtained from 3 phase transformers. This is desirable, both from the standpoint of the manufacturer and the user, the three-phase unit being more efficient, costing less, occupying less floor space and being considerably simpler to install, especially from the standpoint of low voltage wiring.

Reactance

With the early types of furnaces, more care was taken in the selection of the average charge and this practice, together with small transformer capacities and single voltage operation at low values, made the use of external or additional reactance unnecessary. In fact in more than one case, the power circuit had such poor regulation that trouble was experienced with the amount of reactance inherent in the apparatus. One 5 ton, 3 phase furnace installation operated successfully, with single voltage control, with approximately 76 volts between electrodes (44 volts between electrodes and arc), with 700 KW. input. When changed over to 2 voltage operation, the input was increased to 2100 KVA at 150 volts with 1400 KW available at 100 volts for refining, which enabled a heat to be turned out every three hours or faster as compared to previous practice of approximately 1 heat every 5½ or 6 hours. The power consumption was reduced from approximately 830 KWH to 600, and the electrode consumption cut approximately in half. With this increase in capacity and voltage, additional reactance was necessary to reduce fluctuations at the start of the heat, and it is seldom that any up-to-date 2 voltage arc furnace equipment is installed without external reactance. For external reactors there is a choice between air and iron core types; at high voltages and low capacities the iron core reactor may have an advantage in cost, while at low voltages and high

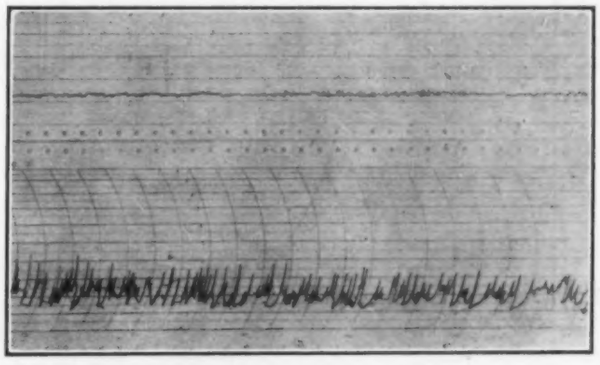


FIG. 11—Wattmeter Curves Showing Comparative Results of Hand and Automatic Electrode Operation of Single Phase Arc Furnaces.

capacities the reverse is the case. The air core reactor gives a straight line voltage drop curve which is not true of the iron core reactor. While the copper losses of the air core reactor are higher than the iron core reactor, it has no iron losses and as a result the total losses are smaller. From the standpoint of the space occupied, the conditions are in favor of the iron core reactor.

In those cases where space considerations contemplate the installation of the reactor inside the transformer tanks, the air core reactor is immediately removed from the discussion. At first hand this plan seems to offer many advantages, but when we consider that the total losses are increased, possibly as much as 1%, that the height is considerably increased and the overall cost probably increased, the whole matter should be subjected to the most complete investigation.

The amount of reactance to be used, its location in high voltage or low voltage circuits, and method of use must necessarily be a compromise What we are really looking for is a variable reactance at a reasonable cost, that will steady the arc at starting and increase rapidly in percentage values as the current increases above normal.

The average powerhouse welcomes the load from arc furnaces, especially when several are grouped

on one feeder. Although these loads fluctuate considerably at starting, for a period whose length depends on method of charging and operating, the fluctuations soon disappear and then the load is balanced, with a power factor of approximately 90 per cent, which is higher than many other industrial loads. Taken in conjunction with resistance furnace loads of the same capacity, this industrial heating combination load is probably superior to 90 per cent of the average motor loads.

Electrode Control

For ten years following the installation of the first arc furnaces in this country, the only automatic electrode regulators were the Thury type, imported from Switzerland. As soon as this business seemed to offer commercial possibilities, domestic companies took up the question and now two automatic electrode controls are built in this country and several foreign types are available.

The electrode motor is called upon to meet unusually exacting requirements, these being to start and accelerate a considerable mass, move it a fraction of an inch and stop it in a smaller distance, this being done many times per minute at the start of a heat. The electrode speed varies with different systems of control, but all are higher than the first furnaces with Thury regulators which gave an average on automatic operation of less than 7" per minute. Present electrode speeds vary from 1½ to

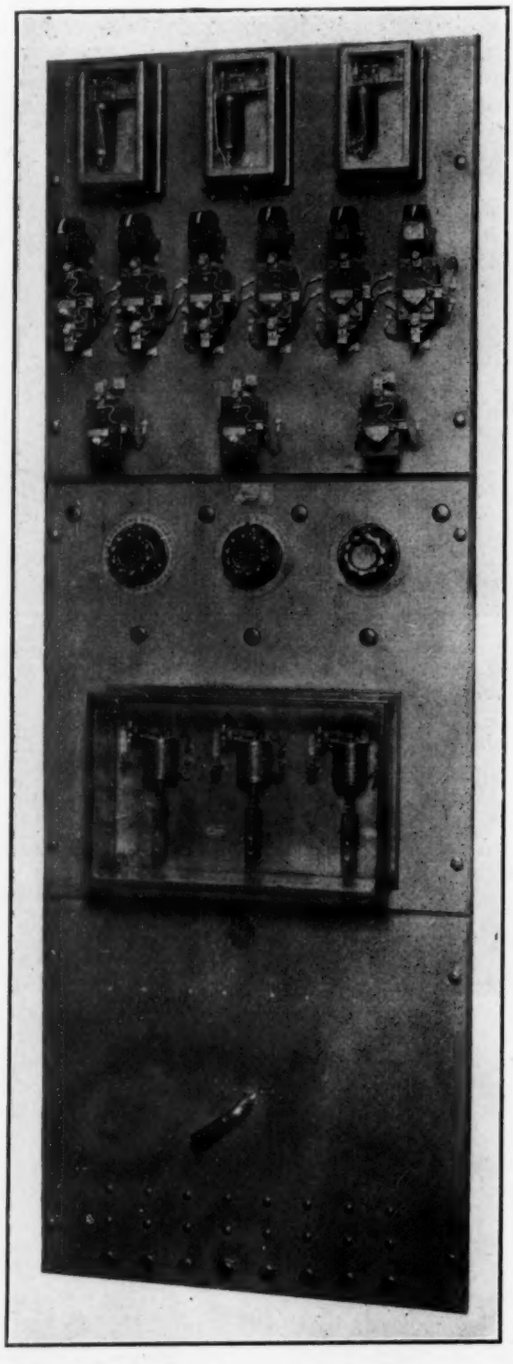


Fig. 12. General Electric Automatic Electrode Regulator for 3 Electrode Arc Furnace

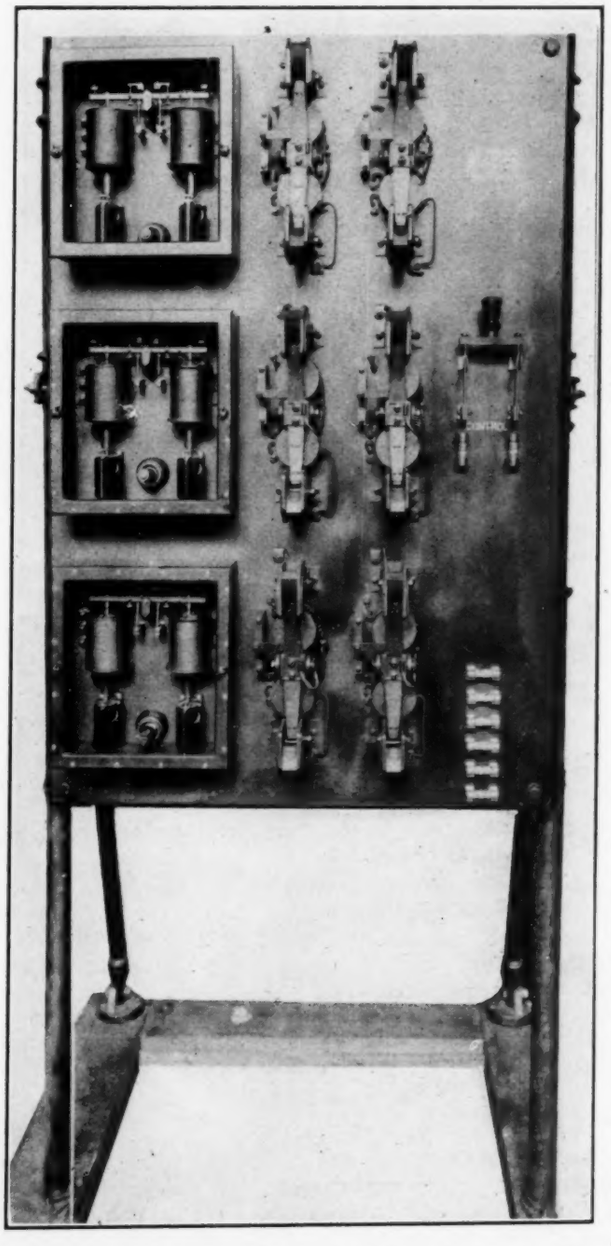


Fig. 13. Westinghouse Automatic Regulator for 3 Electrode Arc Furnace

5 times this figure, even higher figures being considered, effective methods of braking, chiefly dynamic, being necessary to prevent over-running. Field control of motor speed is also used, in both types of furnaces, those where winches are mounted on furnace shell and those where they are mounted separate from the furnace.

Motors

While electric furnaces are tilted by hydraulic and electrical means, the latter method predominates at the present time, either alternating or direct current crane type motors being used with entire success. Solenoid brakes, operating on the motor shaft, are provided to prevent over-travel and a simple reversing controller completes the equipment, that gives sufficient control with a minimum of complication.

On steel melting furnaces, the electrode masts are raised and lowered by cables operated from winches driven almost exclusively by direct current motors. These motors are totally enclosed and are provided with oilless plug type bearings when the winches are mounted on the furnace shell, or semi-enclosed with standard oil ring bearings, when winches are mounted separate from the furnace.

Alternating current motors are used in large smelting furnaces where the fluctuations and resultant electrode movements are small and at infrequent intervals, but for melting furnaces, especially for steel and iron, the best control consistent with a minimum of complications is obtained only by the use of direct current motors.

Furnace Construction and Practice

It is, perhaps, needless to state, that up to date furnaces are much superior to those of 25 years ago, not only from the standpoint of construction, but especially from the standpoint of operation—such as charging, adjusting of electrodes, room available around the furnace and many similar details. These points were taken up in the 1924 report of this Committee, and the reader is referred to that report.

The largest electric furnaces for melting steel, or refining molten steel, in this country at the present time are as follows:

Two 3-electrode Heroult furnaces at Naval Ordnance Plant, Charleston, West Virginia, each of 40 tons rated holding capacity, the transformer furnishing 3300 KVA at 110 volts 3 phase 60 cycles to the furnace. This furnace is used in final refining of molten steel from an open hearth furnace.

One 8-electrode Greaves-Etchells furnace at Ford Motor Company, Detroit, Mich., 50 tons rated holding capacity, two transformers supplying 6000 KVA 3 phase 60 cycles at 130 volts between movable electrodes. On account of the high capacity of the transformers, this furnace is designed for use both in melting and refining steel.

One single ring General Electric 6 ton induction furnace at the Allegheny Steel Company, Brackenridge, Pa., taking 800 KW at 8.5 cycles single phase from frequency changer set. This furnace is used chiefly for refining molten steel taken from melting furnaces.

Induction Furnaces

After many trials and failures the induction furnace, which is essentially a device for producing the highest quality product, has returned to its original design—that is, a single ring, single phase type. Aside from the ordinary technical developments that have come with our increased knowledge of materials, the main difference has been the placing of the coil above the bath and the change in the cross section of the metal as a consequence of this change in the position of the coil. Where, in the old Kjellin type furnace, there was too much circulation of the metal, sufficient to cause destructive erosion of the lining, the metal now circulates gently, a little more than enough to prevent segregation, but well below the point where erosion sets in

In the way of auxiliary apparatus, even small single phase loads at 50% power factor or thereabouts, require a motor generator set, and consequently the first cost of the equipment is high. However, the most perfect type of control is used—field control, and the addition of a load of this kind to any plant almost always means a reduction in the rate charge. If these furnaces were given full credit for this reduction, the actual cost of melting steel in the induction furnace would compare favorably with other methods.

Perhaps the biggest advance in electric furnace matters has been the recent demonstration of the commercial feasibility of melting metals in an ordinary clay graphite or similar crucible, surrounded by an edge-wound copper coil, supplied with power at approximately 500 cycles. This type of Ajax-Northrup high frequency furnace offers many possibilities, not only in the melting of non-ferrous metals and alloys, but also in the manufacture of relatively small quantities of high grade steel, say in 500-pound heats. While this is strictly an induction furnace, no electrodes being used, it does away with one of the disadvantages of the induction furnace, namely, the necessity of holding the furnace up to temperature by holding back part of the charge between heats. This means that if the power should go off the ordinary induction furnace for several hours, it might be necessary to re-line the furnace, this meaning extra expense, and loss in productive capacity. This also means considerable difficulty in changing from one metal or alloy to another, as when the first charge is emptied from the furnace, it is necessary to have at least 25% normal charge of the new metal in molten form.

The Ajax-Northrup high frequency furnace does away with all of this, not only enabling the melter to shift from one metal to another, but also, depending somewhat on the metal, to shut down the furnace and start up again without emptying the charge, in fact the furnace starts up better this way than the normal way. The furnace may be operated either way, that is, by leaving in part of the charge which helps to start the new melt, or completely emptying the furnace. An investigation of the possibilities of this melting agent, should be of interest and profit to those engaged in the development of various alloys, where the charge must be melted under ideal conditions.

Another interesting possibility of this method of heating lies in its application to heating metal rods, tubes, etc., especially of iron and steel. Whether or not it has possibilities in competing with Mr. Bailey's method of heating ingots

in soaking pits remains to be seen, but it is not an idea to be dismissed lightly. The melting developments are too recent to offer definite operating data, outside the figures given by Mr. Willcox below, but as these are only about 10 per cent higher than the most efficient commercial melting means known, the Ajax-Wyatt furnace, the possibilities of this method are certainly large.

Crucible	Metal	Wt. Charge lbs.	KW.	Time in Minutes	KWH. per Ton
Cold	Nickel Silver	636	90.1	109	502
Hot	Nickel Silver	636	92.8	78.6	382
Cold	Yellow Brass	636	99.	64.	332
Hot	Yellow Brass	636	99.5	43.	225
Hot	Copper	636	100.	69.	362

As stated above, the furnace coils take power from a single phase circuit of approximately 500 cycles, at 900 or 1800 volts, and as such will require a motor generator set or some other means of frequency conversion, from the normal power circuit The load from such a furnace, or bank of furnaces, is the ideal load from a synchronous or induction motor driven set, and as such should always have a beneficial effect on the power rate. The equipment is very simple and as such should find favor in the eyes of the Maintenance Department. Altogether, as stated above, it is one of the outstanding advantages in electric furnace development, and as such will bear watching and investigation.

General

As a whole, this has been a very active and interesting year in electric melting furnaces, not only from the standpoint of the arc furnace development, but also the other means of electric melting and heating. The report of this committee as a whole indicates clearly the increasing importance of this subject, as noted many times by the large National Electrical Societies.

*Heating of Ingots by Electricity**

By RALPH A. BUTLER†

SINCE the World War, when quantity production was the thing most desired, consumers have become more and more discriminating, with the result that the competition for the favor of the buyer has forced the producer to give an equal consideration to quality in production along with that of quantity in production. Inasmuch as there is not much of a difference between the production costs of the leading steel producers today, the result is that the greatest profits generally fall to those who get the nearest to capacity operation. These advantages are only temporary, however, fluctuating back and forth and in the end averaging up fairly even among all the well managed companies. It therefore follows that permanent advantages can be best secured, except in highly integrated concerns, by making something different from the others, or by making a particular product or line of products better than competing companies. Those who are able to do this find themselves in the enviable position of being able to demand sufficient premium for their goods so as to insure a regular and generous margin of profit. In case an actual premium is not attainable, a ready market is at least assured. The foregoing applies to the final product turned out, but the same applies equally as well to any intermediate steps affecting the final product.

The blooming of ingots is an intermediate step between the open hearth and the finishing mills and as such is in the position of a middleman. Like all other middlemen, it is the target of general criticism. The Open Hearth has an "alibi" for any defect in its product in the improper subsequent treatment of this product in the blooming process. In turn, the finishing mills can use the same arguments for their advantage. In consequence, it has always been difficult to determine accurately just where defects in steel have developed. Therefore, any movment which tends to standardize blooming practice to the point where the service rendered is so clean-cut as to practically introduce no additional mechanical defects in the steel, will result in fixing the responsibility for quality and will bring about a consequent opportunity for general improvement of the resultant products.

In the past, much of the criticism of the blooming process, when such criticism has existed, has been laid at the door of defective or improper heating of the ingots in the soaking pits. Much of this criticism has been deserved and much undeserved. However, the heating has always been such that it has been more or less of a variable, depending upon the personal equations of the heaters and those in charge. Heaters and heating methods are different wherever steel is made. It therefore follows that any system of heatin, whereby the practice can be fixed with mathematical accuracy, is bound to be an unqualified success in improving the quality of the steel. Lately a method for heating steel has been developed which gives promise of fulfilling this requirement. This method referred to is that of heating ingots by electricity.

Early in 1924, the Donner Steel Co., Inc., installed a trial electric soaking pit for the purpose of investigating the merits of this method of heating ingots as related to a possible improvement of the quality of its products. Owing to limitation of space and the natural desire to proceed cautiously, this pit was designed for one ingot, but subsequently changed to accommodate two ingots. The clearances were figured closely—in fact, too closely, except for the depth, which proved to be about 18" too great. When the ingots were in the pit, the clearances were ideal, but a difficulty arose in extracting them from the pit after they were heated. Quite a few delays were thus encountered as it

*To be presented in connection with Electric Heat Committees report.

†Effic. Engr., Donner Steel Co., Inc., Buffalo, N. Y.

required considerable jockeying to get the crane tongs down over the ingots. This introduced several marked disadvantages, among which were the cooling of the pit for subsequent treating as well as the chilling of the ingot surface itself.

The electric soaking pit covered by this discussion was merely a sheet steel rectangular shell lined with a layer of special refractory insulating material. Adjacent to this was a layer of refractory fire brick, which also served as the interior lining of the pit on the ends. On the sides, the interior wall of the pit was largely composed of a well known refractory brick selected for high thermal conductivity, as well as its refractory qualities. This brick completely surrounded the resistor chambers, which pierced the side walls of the pit for their entire length. One side of the resistor chambers also served as part of the interior lining of the pit, the intervening filling between resistor chambers being built up with standard refractory brick. There were four of these resistor chambers, two on each side, with electrodes at each end, making eight electrodes in all. The base was of concrete, provided with an aperture for disposing of slag, ashes, scale and other refuse which might develop from time to time. The top, which was lined with fire brick, was hinged across the long dimension of the pit and was operated by a compressed air piston with ordinary globe valves for control. For supplying the furnace with a large amount of low voltage current, a 2,200 volt step-down transformer of 150 K.V.A. capacity was used. A voltage variation of from 220 to 380 volts was secured by the use of a selective oil switch connected to the secondary tap of the transformer. A recording wattmeter and an integrating watt hour meter completed the electrical equipment.

When the pit was ready to operate, the resistor chambers were filled with granulated petroleum coke to the level of the tops of the electrodes. The current was turned on and the resistor material soon began to heat up and transfer the heat so formed through the walls of the chambers into the pit itself. Part of the heat was also transmitted directly through a few small openings leading from the resistor chambers to the inner walls of the pit. What heat did not pass into the pit was lost by radiation from the outer casing.

When first operated, difficulty was experienced with high temperatures building up in the resistor troughs, causing slagging of the resistor walls and the adjoining refractory brick, eventuating in wall failures. The trouble was diagnosed as insufficient wall relief, or insufficient radiation, and efforts were made to combat this difficulty. The resistor chamber walls were then rebuilt with passages in them completely surrounding the resistor chambers, having openings inside the pit, both above and below the resistor chambers. In addition to this, direct openings from the pit to the resistor chambers were constructed. This change in construction solved the problem to the extent that the life of the pit was trebled before repairs became necessary. This remedy was elaborated to the limits which the construction of the existing pit would allow, and from this point on, the pit was operated without further change. If the dimensions of the pit had not proved a barrier, the wall relief measures could have been carried on still further and to such an extent that the life of the pit could have been extended for long periods of time. However, these relief measures brought with them their share of difficulties. To build the air passages required the sacrifice of over half the insulating material next to the shell, and, when the pit was under load, the increased radiation caused a temperature difference of about 100° in the shell of the pit. In this manner the heat losses were probably doubled and consequently resulted in the use of that much more current to overcome this disadvantage.

The temperature of the pit was determined by means of a recording electrical pyrometer, the thermocouple being inserted through a hole in the lid of the pit. By means of this thermo-couple, together with the aid of an optical pyrometer for checking, the heating was controlled.

When first operated, the ingots were not heated sufficiently, owing to the fact that although the thermocouple indicated a temperature which was ideal for rolling, nevertheless the ingots were too cold and plainly showed so in rolling. Optical readings on the ingots removed at this time showed readings of 150° less temperature than the thermocouple. These variations were probably due to differences in calibrations and to the location of the thermocouple itself. Later experimenting with the position of the thermocouple showed variations up to 100° in temperature. However, these differences were all allowed for and the experimenting continued.

By heating low carbon steel and also 100 carbon steel to the points where they showed unmistakable evidences of overheating, the maximum temperature for heating each class of steel was determined. This method was continued with the result that proper temperatures for heating steels of varying carbon contents were soon discovered. These limits were so accurate that it was possible to determine within a surprisingly narrow range of temperature the degree of heat necessary to insure a very satisfactory rolling temperature. Moreover, it was soon ascertained that a certain variation in carbon content required a certain fixed variation of heating temperature—hence a table was devised which proved very valuable. This table was not only used for carbon steels but for alloy steels as well.

The pit was constructed so that it was practically air tight. A layer of coke braize was placed in the bottom, the combined effect producing a decided reducing atmosphere. This practically eliminated the formation of scale and it was only when the ingots were removed from the pit that the scale began to form rapidly. This scale was very thin and never was over 3/32" thick and, as nearly as it was possible to determine by the weighing apparatus in use, it was considerably under half of that produced by gas heating, which in this case was coke oven gas.

Owing to the time required for bringing cold ingots up to temperature, after more or less experimenting with them, only recently stripped ingots were used. The average skin temperature of these ingots was 1660° F, based on observations of several hundred ingots with an optical pyrometer. Again, after the ingots had been heated and removed from the pit, optical pyrometer readings were taken at various points during the rolling process in the blooming mill, but owing to scale formation, it was impossible to get accurate results. It was then decided to take all optical

readings after the fifth and the ninth passes on the blooming mill. At these points the scale was practically all removed, affording a surface which gave a fair indication of the temperature of the ingot. In any event, this procedure was finally adopted as the standard procedure and was used thereafter. This method gave very good checks on the temperatures and proved a means of correction to the heating scale evolved, whenever the recording pyrometer failed to record properly. It also gave an accurate comparison of the gas heated ingots and the electrically heated ingots.

Upon rolling, the electrically heated ingots, after the proper temperature of heating had been determined, broke down ideally. They went through the rolls straight and showed no signs of twisting or bending. In addition, they gave evidences of rolling easier than the gas heated ingots. On those ingots which were finally finished in an 18" continuous mill in series with the blooming mill, the recording meter showed a reduction in electrical peak loads on the mill drive running up as high as 25% in some cases and averaging consistently below the peaks on the gas heated ingots.

The results of our experiments have demonstrated in a practical way that ingots can be heated electrically and in a manner which will insure almost ideal performance when going through the rolls in the mills. If proper heating of ingots will help in the minimizing of "tears," aggravated in rolling, then there can be no question about the efficiency of this method. This, taken with the decrease in power to roll together with the reduced wear and tear upon the mechanism of the mills, are factors of great importance and have a very direct bearing on the final cost of the resulting products rolled. Then again the decreased loss in scale is a consideration of very great value and, in heating certain classes of material, would no doubt be of paramount importance, especially in the puddled iron industry.

The costs of operation and maintenance of the experimental electric soaking pit were higher than ordinary costs of heating, but there were many extenuating factors. If the trial pit were to be built over, the costs of maintenance could be cut down to at least one-third of the costs which actually did develope. The pit was so designed that a slight failure in a lower resistor chamber practically necessitated a complete rebuilding of the side walls of the pit with the consequent breakage of expensive heat conducting brick, together with the use of new bonding material and the expense of labor, etc. A pit of a new design, based on the experience with the old pit, would give results altogether different and certainly more gratifying and conclusive. The average power consumption for heating two ingots of 3.3 gross tons each, was 531 Kilowatt hours. When the pit was working ideally and very hot ingots were charged, a figure of as low as 100 K. W. hrs. was recorded. The figure of 531 Kilowatt hours can be very materially reduced by a pit of a new design. Based upon a superficial area, the wall loss of a six-ingot pit would be roughly two-thirds as much per ingot heated as for the two ingot pit. Then again, the condition of deficient insulation could be corrected for a new pit, reducing the wall loss to at least half of that prevailing on the experimental pit. A figure of 450 K. W. H. for two ingots weighing 3.3 gross tons each could easily be attained and could probably be maintained for ingots charged with a superficial temperature of 1660° F.

A commercial electric soaking pit should be so designed that wall losses are reduced to a minimum. Furthermore, it should have resistor chambers of generous cross section, so that heavy currents can be forced through the troughs without excessive temperatures building up in the chambers. Such a change would result in decreased consumption of resistor material and would lessen the tendency to slag or to corrode the resistor chamber walls. Then again, the resistor chambers ought to be so designed that the heat transfer is immediate and direct so that the difference in temperature between the resistor material and the pit itself is minimized. Furthermore, the resistor chambers should be so built that they are easily accessible for repairs and for charging new resistor materials. It is necessary also that the stuffing boxes for packing the electrodes be of generous size and so arranged that the packing for the electrodes can be done easily. Lastly, the electrical capacity should be such that the pits can be speeded up upon occasion to such an extent that the total elapsed time from charging to withdrawing be not in excess of four hours.

If the foregoing suggestions as to design are carried out, an electrical soaking pit can be built which will give almost ideal conditions of heating ingots and at a total cost which will compare favorably with many heating costs. It is entirely probable that further use of this method of heating would unfold further refinements which would lead to quite a general use of electric heating. In any event, this method of heating has unlimited possibilities and represents a distinct contribution to the art of preparing ingots for rolling.

NOTICE

SPECIAL FEATURE, SAFETY DIVISION

The Safety Section's activities will be one of the Convention's special features and will be held Monday, September 14th, 1925, in the main ball room of the Benjamin Franklin Hotel.

Beginning with a luncheon at 12:30, in the main ball room of the Benjamin Franklin Hotel, the Safety Section will present a program which will be of interest to every Safety Director and Electrical Engineer in the Iron and Steel Industry.

Mr. L. H. Burnett, Assistant to the President, Carnegie Steel Company, and Chairman of the Safety Section, will act as Chairman of all the activities in connection with the Safety Section. Mr. John Oartel, Chief of the Safety Bureau of the Carnegie Steel Company, will present a paper of unusual interest to everyone in the Steel Industry. Mr. Henry A. Renninger, Vice President, Lehigh Portland Cement Co., and also Vice President of the National Safety Council, will take part in the day's program.

Make your reservations early for this luncheon.

*Auxiliaries and Auxiliary Drives for Steam Electric Generating Stations**

By A. L. PENNIMAN, JR.† and F. W. QUARLES‡

IT IS intended that this paper shall be a study of problems of station auxiliaries and auxiliary drives as influenced by the design of Steam-Electric Generating Stations, based largely on experiences obtained in operating a fairly large Central Station.

It is felt that this study has been necessarily narrow in scope as applied to the generation of electricity, by steam, in the steel mill. However, it is hoped that attention may be directed to certain essential features which have been developed in Central Station design and operating practice.

Whatever type of auxiliary drive is selected, the outstanding requirement is that in addition to being inherently reliable, it should so influence station design that the largest amount of net electrical power may be generated for the least amount of money, including, of course, fixed as well as operating charges. However, reliability is of prime importance. Therefore, a machine very economical in the consumption of power, or materials, should not for this reason alone be considered to have the lowest overall cost. At times it is, of course, hard to place a monetary value on reliability; nevertheless, due to the many factors involved in the production of electric power by steam, it is evident that the smaller details of the process must be as reliable as the larger ones, since continuity of output for the plant as a whole is essential.

In the first place, assuming a generating station consisting of water tube boilers, steam turbines,driving alternating current generators, operating with suface condensers and a sufficient supply of feed-water for boilers, a sudden reduction of the load results in a lowering of the demand for steam, and this must be taken up momentarily, at least, by the water in the boilers. There are also storage points in the steam circuit; namely, the condenser and hotwell, where water may be delayed in its delivery to the boilers. This requirement is usually met by providing a sufficiently large storage tank with reliable feed pump and drive.

Next in importance is the supply of circulating water for the surface condenser. Failure of the circulating water supply usually results in the loss of that generating capacity which is served by the condenser affected. This necessitates reliability of the pumps, pump drives and power supply as well as that of the piping and water supply. The more sudden the failure, the quicker the loss of vacuum in the condenser, with the final result that the steam from the main unit must be released to the atmosphere. The condenser unit is very rapidly filled with steam above atmospheric pressure, the water in the interior of the tubes soon reaching boiling temperature, necessitating cutting the unit out of service. An attempt to immediately start the flow of circulating water is not advisable on account of the danger of water hammer and the probability of damage due to sudden cooling of the condenser and piping. When the circulating water supply actually fails, the usual practice is to allow gradual cooling to a safe temperature before resuming operation.

Of equal importance is the air supply to the boilers and the removal of the gaseous products of combustion. The effect of a failure in this case is not so sudden, although it is felt in a very short time. Naturally, if for any reason the removal of waste gases ceases to function, a reduction of air supply is immediately necessary. The failure of a condenser air or condensate pump is also felt in a few minutes time, although not as quickly as loss of circulating water to the condenser. Immediate steps can be taken, however, to rectify this condition without interrupting service. A failure of the remainder of the plant auxiliaries will not be likely to affect the plant output unless they extend over a fairly long period of time. Coal and ash handling are usually so classed, depending, of course, on coal bunker and ash hopper sizes.

Auxiliaries Directly Driven by Steam

The steam turbine drive for auxiliaries has been well adapted to this service on account of its relative reliability, its wide application being based largely on this feature. The non-condensing type of turbine is generally used for a number of reasons. The small sizes required make the use of individual condensers prohibitive. The improvement of plant efficiency by use of the exhaust of these turbines to heat the water fed to the boilers was early realized. A balance may usually be obtained at some definite load, but is difficult of attainment at other loads, unless combined with other types of drive. The power requirements of the auxiliaries are ordinarily such that too much steam is available at light loads. This steam when allowed to discharge to the atmosphere must be replaced, usually in the form of make up water to the boilers.

Heat lost in transmission of steam to and from small turbines has always been of some consequence and with the advent of higher steam pressures and temperatures this loss is of still greater magnitude. The reliability of the small turbines is also affected by the use of this higher temperature steam, and, of course, maintenance and first cost will be increased.

A method which has found some favor in connection with obtaining a better station heat balance when using steam driven auxiliaries has been the bleeding of steam from the main turbine units to open feed-water heaters. Except with specially designed turbines, the gain is lessened because of variation of pressure at the bleeding point. This disadvantage may be offset to a certain extent by providing more bleeding points, together with adequate control. Turbine units have also been arranged to take in steam from the auxiliaries when there is an excess. With this design, complica-

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

†Supt. of Steam Stations, Consolidated Gas, Electric Light and Power Co., Baltimore, Md.

‡Asst. Supt. of Steam Stations, Consolidated Gas, Electric light and Power Co., Baltimore, Md.

tions may ensue, unless the back pressure on the auxiliary exhaust lines is held above atmospheric, due to the possibility of air leaking into the main unit; a small air leak causing a decrease in vacuum, such decrease resulting in a considerable loss of economy. A dependable non-return valve is sufficient when bleeding; however, when taking in steam, the regulating valve must be under the control of the governor of the main unit.

Auxiliaries Driven by Motors Supplied With Power from Main Bus

Auxiliaries driven entirely by motors with power obtained from the main station bus have the advantage of simplicity of operation. The installation can also be made in a very simple manner. A serious disadvantage is incurred, however, by reason of the effect of any interruption to the main station bus shutting down the entire plant, the recovery of which may be indefinitely delayed unless some standby service is available. In an effort to relieve this condition some designers have made use of a combination of the small steam turbines, and also motors driven from the main bus, furnishing duplicate steam and motor driven equipment; or certain auxiliaries may have a motor on one end and steam turbine on the other. Usually that equipment not requiring an unfailing supply of power is driven by motors supplied from the main bus. Motors have been so developed that they are inherently very reliable, while space requirements, attention and maintenance are lower than those of the small steam unit. Motor control can be made dependable and somewhat more flexible than is the case of the small steam driven auxiliaries. The application of motors to all auxiliaries is most satisfactory if the supply of power is reliable and some method provided for satisfactorily heating the feed-water.

Auxiliaries Driven by Motors Supplied With Power from House Turbine

The house turbo-generator was a logical step in providing an unfailing supply of power for motors driving auxiliaries. Its use also had the advantage that better economy could be obtained from a larger turbine than from several smaller ones. The economy of this scheme is also increased when the house turbine is operated at partial vacuum. Its efficiency, however, is not as high as that of the main unit, while when compared with the use of small turbines, the steam and exhaust piping required is much less. The house turbine gives the necessary reliability and can, of course, be more easily controlled than several small turbines in maintaining the heat balance and can be much more readily adapted to higher pressure and temperatures than can the smaller turbines.

Any system of motor drive suffers the handicap of conversion of energy from mechanical to electrical, and back again to mechanical. In this conversion process, however, speed regulation is readily effected without resort to gears. In the appplication of small turbines to many of the auxiliaries, direct connection means a sacrifice in efficiency unless a reduction gear is used. The small turbine for reasons of efficiency, and first cost, is designed for speeds higher than those usually required by the auxiliaries. In some cases a compromise is attempted by having the turbine and driven equipment designed for a speed, lying somewhere between the most economical speed of either, thereby sacrificing efficiency of both pieces of equipment. However, the use of reduction gears is more common.

When the house turbine generator is of the direct current type it no longer possesses this speed transformation advantage, because of the fact that direct current generators of the size required, are not of suitable speeds. This has resulted in the application of a reduction gear to the house turbine unit.

Direct current motors, from one viewpoint, are well suited to drive some of the plant auxiliaries because of the necessity of speed variation. In other cases a variation of speed, while not being a necessity, results in economy of power. When the power to drive direct current motors is obtained from a house alternator, a motor generator set, rotary converter, or rectifier is required. So far, engineers have hesitated in applying rectifiers of the size and voltage required. Any of these conversion methods introduce additional losses. The use of a house turbine unit, while furnishing a dependable source of power, suffers the same disadvantage as is the case of auxiliaries directly driven by steam. Its use represents the concentration of a number of small units into a larger unit. There still remains the advisability of controlling its output to suit the economical requirements of feed-water heating without paralleling it with the main station bus, except through a loosely coupled connection. One method has been to use what are termed transfer motor-generator sets, the purpose of which is to transfer power from the main bus to the auxiliary bus or vice versa. These sets, of course, have losses and require attention and maintenance. Protection must be provided so that an interruption on the main station bus does not result in a serious fluctuation in voltage on the auxiliary bus. Another method of control has been used in which two power sources are provided for the auxiliaries, one being the main station bus, the other being the house turbine. Load is transferred by quickly switching individual motors, or groups of motors, from one source of supply to the other. The control wiring must be so arranged that essential auxiliaries can be switched immediately to the house alternator supply in case of an interruption of power from the main station bus.

Auxiliaries Driven Direct From Shaft of Main Unit

This method is not applicable at present to turbine units of the size under consideration. This scheme has been in use on some engines built a number of years ago and is still used to some extent. It represents, however, a line of thought which has resulted in the more or less ideal scheme presented below.

Auxiliaries Driven by Motors Supplied With Power from Generators Connected To Shafts of the Main Units

Power when obtained in this manner is highly dependable and affected to a negligible extent, by an interruption on the main station bus. The effect of a short circuit on the main alternating current generator results in a negligible change of speed of the main unit, due to the low power characteristics of the short circuit. It is obvious that so long as the shaft speed is held reasonably constant, the ring of the process of power generation is unbroken and quick restoration of service after an interruption, is no longer dependent on the auxiliary power supply. We obtain the advant-

age of the house turbine unit without the turbine part of the unit and we have for our prime mover, a turbine more efficient than the smaller unit.

This method of supply, when considered alone, however, does not compare very favorably with the previously mentioned methods, because of the heat rejected to the condenser; but, when combined with the use of the regenerative cycle where heating of the feed-water is by bleeding of the main unit, it assumes a much more favorable aspect. In the case of heating the feed-water by steam rejected from the house turbine unit or small turbine units we, in effect, obtain by-product power at small cost, the cost being dependent on the heat efficiency of the turbine. In consequence of its size the main turbine is still more efficient, and is able, for this reason, to produce a still greater amount of by-product power by steam bled at a like pressure and temperature. The further the steam is allowed to travel through the main turbine before extraction the greater is the by-product power, thus, it would seem desirable to bleed at many points to obtain the maximum amount of by-product power. However, other factors influence the over-all cost to such an extent that the economical number of bleeding points is limited.

It has become common practice to use a shaft driven exciter for a dependable supply of excitation current for the main unit, even though this places the design of the exciter at a disadvantage, from the standpoint of speed. The next step was the proposal of increasing the size of the shaft exciter to care for the power demands of the important auxiliaries. This gives a simple method of obtaining the advantages of direct current motors, in those services which are benefitted by economical speed variation, and at the same time reduce the loss which is incurred by the extra energy conversion of alternating current to direct current. Such a plan has been applied and its operation has been economical and satisfactory. However, because of the difficulties of the design of such high speed direct current generators, the manufacturers of large turbo-generators have been loath to furnish such units. Under short circuit conditions the direct current generator does not behave nearly so well as the alternating current generator. The D. C. house generator has the further disadvantage, that in order to supply emergency power from the main bus, it is necessary to have motor generator sets of ample capacity running at all times.

As an alternative to the shaft driven, direct current generator, consideration should be given to the shaft driven, alternating current generator. In this case the design is comparable to that of the house alternator and does not require such special treatment as the direct current unit. In comparison it can be designed to have a very high efficiency, low first cost, and low cost of maintenance. It is quite obvious that the commutator and brush maintenance will be high on the high speed direct current unit. The action of the alternating current generator under short circuit, is much more favorable than that of the direct current generator. As a safeguard, protection may be supplied in the form of a field destroying device and balanced relays, such as in the case of the main generators.

Since the power supply from the shaft driven, alternating current generator is dependable, it may be used to drive a motor generator set to furnish direct current for excitation and for power supply to such motors as may be deemed desirable. The direct current generator, in this case, does not need to be special. Unless sufficient gain is obtained in the use of direct current motors to offset the conversion losses, it is advisable to apply alternating current motors, particularly of the squirrel cage or wound rotor type, since they are cheaper both in first cost and maintenance and are inherently more reliable.

Reference has been made to cases demanding adjustable speed. The stoker drive, for instance, requires a constant speed for each given rate of coal feed, though the torque may not bear a fixed relation. As the load varies over a wide range the stoker drive motors should have a speed range of at least six to one. The shunt wound direct current motor has been satisfactorily applied to this service, giving the required speed range. Application of squirrel cage induction motors requires the use of some adjustable speed changing mechanism with its attendant losses and upkeep. Wound rotor motors are not so well adapted, because of the varying torque demand, which, in turn, causes undesirable speed variations.

In the case of centrifugal pumps and fans operating under heads composed almost wholly of friction, variation of speed is economically desirable, though not necessary. With such a large decrease in power demand, with a given reduction in speed, the secondary resistance losses in a wound rotor induction motor do not assume such large values. For this reason they can be compared very favorably with direct current motors. Brush shifting alternating current motors have also been applied to fan service. This type of motor retains a fair efficiency over a considerable speed range. The first cost and cost of maintenance, however, is higher than that of the wound rotor motor.

Classes of Auxiliary Service

Auxiliaries of the steam electric generating station may be divided into three general classes with respect to the necessity of an unfailing power supply:

A. Equipment little affected by an interruption in power supply, other than stoppage of its own output or service. Coal and ash handling equipment, circulating water screens, sump pumps, machine tools, etc., may be placed in this class.

B. Auxiliaries which are required only when the station is carrying load, and must be shut down upon occurrence of an interruption resulting in loss of load. Forced and induced draft fans should be placed in this class, as it is desirable to check the fires upon the occurrence of a general interruption. This service is well adapted to be supplied by motors, taking their power from the main station bus, since a general interruption will automatically stop this equipment. Automatic starting panels may be used to provide immediate starting upon restoration of voltage on the main bus. In central station practice, restoration of the main bus voltage, after an interruption, does not usually result in the load becoming normal until the elapse of approximately ten minutes. This provides ample time for furnace conditions to become normal.

C. Auxiliaries which are intimately related to the production of power, the stoppage of which may

result in disaster, or in a prolonged interruption. Boiler feed pumps, circulating pumps, and exciters (in the order named) are placed in this class. Condensate pumps should also be included when arranged to discharge directly into the boiler feed pumps. This class of auxiliaries is by far the most important of the three mentioned, and, of course, requires an unfailing supply of power.

A Specific Application

In order to bring out the salient features of the method of auxiliary drive, using motors supplied with power from a generator connected to the shaft of the main unit, a specific problem has been considered. This application is that of a plant of 30,000 kilowatts capacity, consisting of three turbine units, each of 10,000 kilowatts rating. Six boilers of approximately 1,000 horse-power capacity were selected. In view of recent developments, a steam pressure of 325 pounds per square inch gauge, with a total temperature of 625° F. was considered conservative. The boilers may be of the so-called horizontal water tube type with convection type superheater. The walls of the combustion space may be of the water cooled type while further economy may be secured by preheating the furnace air to an average temperature of 300 to 350° F. Induced draft fans would be used, providing a low cost chimney. With use of a fair grade of Pittsburgh coal, the fuel burning equipment may readily be of the under-feed stoker type with clinger grinder; the air supply being furnished by forced draft fans. The drive for induced and forced draft fans should consist of adjustable speed wound rotor induction motors in each case. The stoker and clinker grinder drive would be adjustable speed shunt wound direct current motors supplied by a motor generator set.

This covers the principal features of the steam making equipment, and we shall next direct our attention to the main turbine units.

A pressure drop of twenty-five pounds per square inch gauge in the piping from boiler drum to steam turbine inlet is allowed, making three hundred pounds per square inch gauge available at the turbine inlet. On the basis of 1½" mercury absolute pressure at the turbine exhaust, and the initial steam conditions of 300 pounds per square inch, and total temperature of 625° F., the following water rates may be expected with straight condensing operation:

Kw. load	Lbs. per kwh.
5,000	11.80
7,500	11.15
10,000	10.95

The number of bleeding points giving the best economy, is dependent upon a number of factors. The principal ones are: first cost (including cost of providing the outlets on the main turbine, heaters, piping, valves, traps and structure costs), space requirements, gain in by-product power, operating costs (including operating attention, power for pumping, and maintenance), and in addition to these the possibility of obtaining all increase in feed-water temperature from other sources, such as economizers.

Bearing in mind the various factors mentioned, it is hardly desirable, in this instance, to bleed from more than two points. Referring to Fig. 1, the steam conditions at the two bleeding points may be noted. The highest pressure point is such that it is neither necessary to apply boiler pressure to any of the heater tubes nor to place the surge tank at a great height. The use of a surge tank gives a certain flexibility to the layout, and is very desirable, and with the present standard design centrifugal pumps, it is a necessity. By the use of specially designed pumps (with some sacrifice in efficiency) the surge tank may be eliminated and all of the water storage placed at a lower elevation. However, because of the difficulty of application of such pumps, it is desirable to use an elevated surge tank. An evaporator is used because of its value in the reduction of losses due to boiler scale. Though applied in single effect form, obtaining its steam from the highest pressure bleeding point, it is applicable to other points of the cycle.

We have the two-stage steam jet air pump, selected because of a number of advantages it possesses when equipped with inter and after condensers using condensate. It is a stationary piece of apparatus, providing very reliable service, is of low first cost and requires but little maintenance or operating attention. Its efficiency is comparable with that of the hydraulic or reciprocating air pump. The vents of the bleeder heaters may be piped to the inter condenser; thus, not imposing any additional duty on the primary jets. This is a considerable advantage, since the compression from condenser pressure is the more difficult stage of the total compression.

Condensate has been used in the oil cooler to provide a source of clean cooling water, as well as to re-

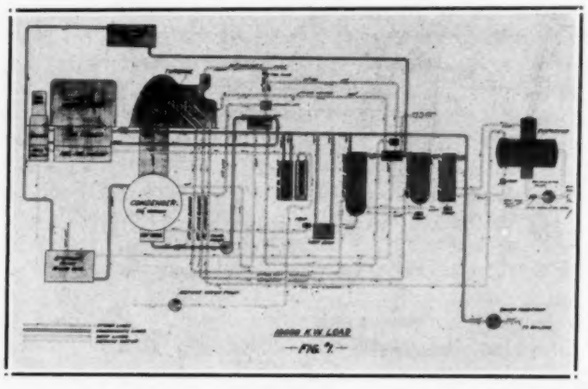


FIG. 1

cover the slight amount of heat rejected by the bearings. A generator air cooler has also been included in the condensate circuit to recover the heat incident to the production of electrical energy—an item of considerable importance. The generator air cooler is a fairly recent development, and has several very real advantages; viz., the elimination of air ducts connecting to the outside air, together with the air washing equipment. The cooling air system can be made tight and thus eliminate deposit of dirt on generator windings. The generator fire hazard can also be materially reduced, particularly if a closed system is used with hydrogen as the cooling medium.

All of the auxiliaries are provided with motor drive with the exception of one boiler feed pump, and a relatively small turbo-generator, both of which will be used at such infrequent intervals as not to warrant any expenditure to recover the heat in the exhaust. The

boiler feed pump should be at all times connected to the service water system and should discharge into the auxiliary boiler feed line so that in case of emergency this pump is available by simply opening the throttle valve.

The auxiliary turbo-generator need be of only sufficient size to drive the auxiliaries of one main turbine, and its complement of boilers, under no-load condition of operation. This generator should be fitted with a direct connected exciter of sufficient size to furnish excitation for one of the direct connected auxiliary generators as well as for the stoker motors for one boiler, together with the emergency lights.

Fig. 2 shows the general outlay of the auxiliary power supply. It will be noted that each main turbine is fitted with an auxiliary generator of sufficient ca-

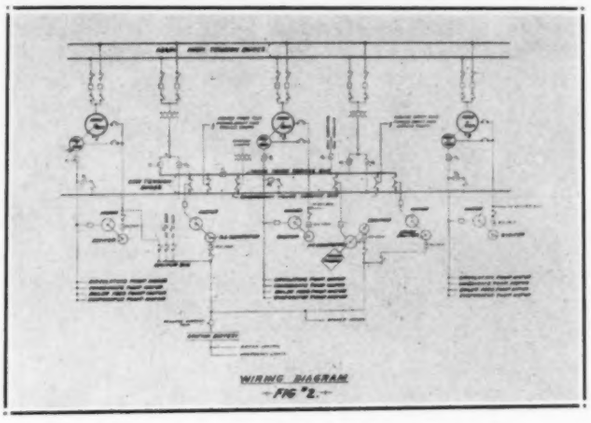


FIG. 2

pacity to furnish power for the circulating pump, boiler feed pump, exciter motor, condensate pump motor and evaporator circulating pump motor. Two banks of transformers are provided, either of which is capable of handling all of the boiler plant auxiliaries, together with the station lights. The low tension side of the transformer banks is arranged so that either of two buses may be supplied with power. The upper, or operating bus, will be normally used. This bus is sectionalized by the switch E-1. Each section of the operating bus serves one-half of the boiler room auxiliaries. The transformers are protected by balanced relays so arranged that in the event that either bank should be disconnected, the bus sectionalizing switch (E-1) will close and the switches supplying non-essential auxiliaries (E-2) will open.

The auxiliary generators are also protected by balanced relays. In the event of the failure of any generator, its load is immediately transferred to one of the service transformer banks by means of the lower, or emergency, house service bus. This bus is at all times energized by one of the transformer banks, while the load normally carried by any of the auxiliary generators may be transferred to this bus by opening the individual auxiliary generator switches (A-1, A-2, A-3, as the case may be), and by closing the corresponding switch to the emergency house service bus (B-1, B-2, B-3). Switches A-1, B-1 and A-2, B-2 or A-3, B-3, should be so mechanically and electrically interlocked that in the event of any auxiliary generator switch being opened, either manually or automatically, the corresponding switch, connecting the interrupted service with the emergency bus, will automatically close. It is, of course, essential that these switches be so arranged as to preclude the possibility of the auxiliary generators becoming paralleled with the main bus. It is, of course, necessary to start up the auxiliaries of a turbine, which is to be put on the line, by means of the emergency bus and the house service transformers, or the auxiliary turbo-generator, in which case it is necessay to switch over to the auxiliary generator by manually operating the necessary switches when the main unit has come up to speed and voltage has built up to normal on its auxiliary generator.

A single motor driven exciter is provided for each unit of sufficient size to supply excitation to both the main and auxiliary generators. Emergency excitation is provided by an additional motor driven exciter, which takes its power supply normally from the emergency bus, and which is available for operating the turbine room crane and as a spare to the M. G. set which normally supplies power for the stoker motors, and floats the control battery.

The above arrangement provides a reliable source of power for the essential auxiliaries, which in turn is backed up by the main station buses, as well as by an emergency turbo-generator for starting up the plant.

There are three sources of excitation. Power supply, for the motor driven feed pumps, is further backed up by a steam driven emergency pump. The normal power supply for all auxiliaries is provided by the main turbines, which are the most efficient source of supply. The fullest utilization of the regenerative

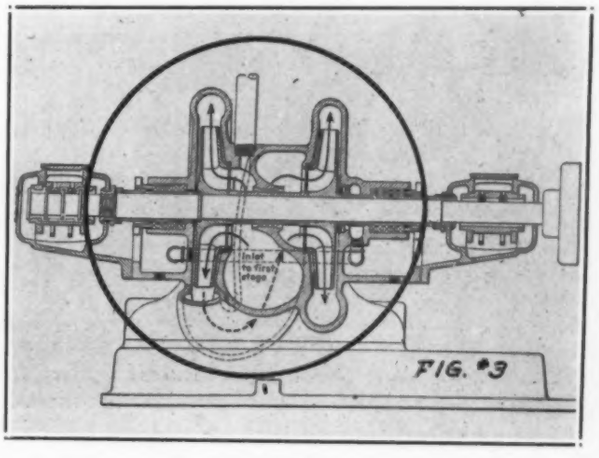


FIG. 3

cycle is provided for without any complications, while the wiring layout is on the unit principle, and is extremely simple and inexpensive.

The condensate from the steam space of the heaters is discharged by means of traps. The heaters are arranged so that this condensate drains, by gravity, when all are at the same pressure. With dependable traps, this condition assures safe and quiet operation. When discharged from the high pressure heater into the lower pressure heater, some of this condensate flashes into steam and, in effect, displaces some of the lower pressure bled steam. The possibility presents itself of pumping the heater drips into the main condensate stream at the point of leaving the heater. However, the cost and diffi-

culties of this method do not seem to justify its application on units of this size.

Some of the heater condensate, if discharged directly into the hotwell, would flash into steam. thus losing its heat to the circulating water. A heat exchanger is provided in the layout to recover a large part of this heat. Attention is drawn to the location of the trap serving the sixth stage heater (Fig. 1), this location being necessary to cause proper functioning of the heat exchanger;

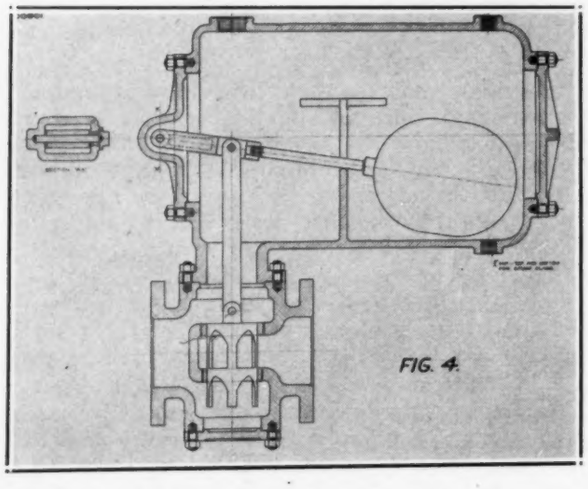


FIG. 4

otherwise, the temperature difference will not allow much exchange to take place (the exchange under some conditions would actually be in the wrong direction).

The steam jet, after condenser surface is made large enough to serve the secondary jets, and also to condense the gland leakage steam coming from the main turbine; thus, recovering the gland losses.

No deaerating equipment has been supplied, as it is considered much more desirable to keep the condensate from becoming contaminated with extraneous gases than to provide special apparatus for removing such gases as may be picked up in the circuit, due to poor design or careless operating methods.

In order to provide against air leaking into that part of the system which operates at sub-atmospheric pressure, it is essential that the surge tanks be steam sealed; that a minimum of valves be installed in the water and vacuum lines, the necessary valves being equipped with properly designed stuffing boxes; and that the hotwell pumps be so designed that neither outside shaft gland be under vacuum (Fig. 3). When hand-operated valves are used, it is comparatively easy to guard against stuffing box leakage by the use of long stuffing boxes which can be set up fairly tight, but where float operated, or other automatic types of valves are used, this is not feasible, as there is usually only a limited amount of power available to operate the valve; hence, it must be practically frictionless. Under such circumstances, traps and float valves should be used which are so designed as to eliminate all stuffing boxes, thereby preventing leakage as well as minimizing the friction of the moving parts. Fig. 4 shows a section through a liquid level controller which may be used either as a trap to drain stage heaters, as a make-up valve, or for any service requiring the accurate control of fluid level.

The installation of bleeder heaters has, in some cases, presented a difficult problem for the designer, particularly if provision was made for removing the tube bundle for inspection or cleaning. The question of space is answered fairly well by placing the heaters on end, as there is in general plenty of space available for withdrawing the tube bundle in a vertical plane. Unfortunately, the floating head type of heater does not lend itself well to installation in this position. Furthermore, the floating head type, as usualiy designed, does not permit of removing the tube bundle. The problem of installing the air baffle in heaters, constructed with two tube sheets, is also one that has not yet been solved to the writer's satisfaction. All of the above difficulties are easily taken care of by the use of what has been termed the "hair-pin loop" type of constructoin. (Fig. 5), where only a single tube sheet is used. This con-

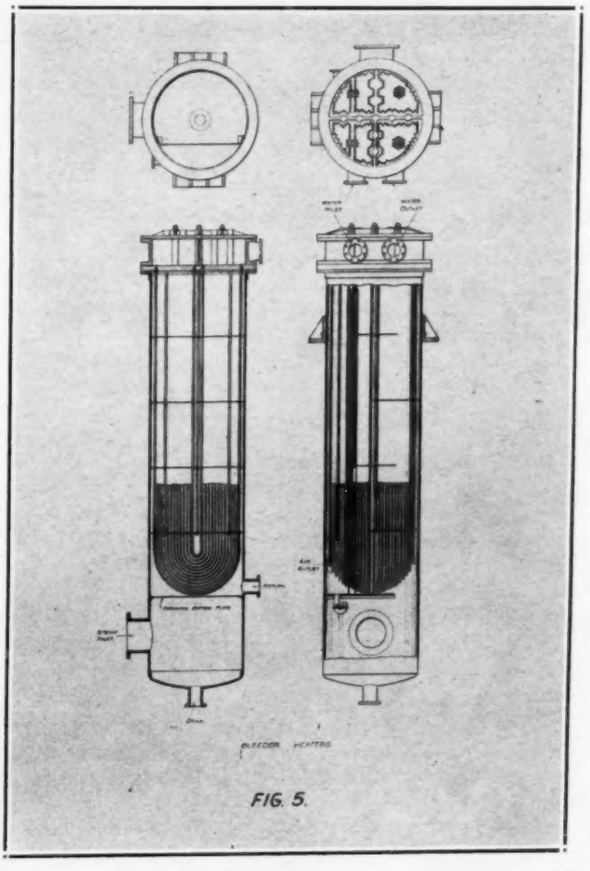


FIG. 5

struction permits of the use of suitable baffles on the steam side of the tubes, the proper installation of an air baffle which may be tested for tightness during assembly, one-half of the joints are eliminated, the friction loss through the heater is greatly reduced, and finally the heater may be easily dismantled for inspection, the tube bundle being readily withdrawn by the turbine room crane.

The regenerative cycle lends itself to the unit system of auxiliary apparatus so that each main unit will be provided with its complement of circulating pumps, boiler feed pumps, air pumps, heaters and evaporators. For units of the size under consideration, each main condenser may be provided with a single circulating pump, which should be provided with motor drive arranged for 40 per cent speed reduction in order to take advantage of the seasonal temperature range of the circulating water. The pumps serving the three condensers should discharge into a common header which, under normal conditions, would be sectionalized, but which might, in emergency, be operated as a common system, permitting of the three condensers being served by two pumps. This emergency condition would entail no lowering of the vacuum, other than at times of high temperature circulating water, and would even, under this latter condition, not materially affect the plant output.

A three-element, two-stage steam jet air pump, with inter and after condensers, should be provided for each unit. The three elements may be served by single condensers, and should be of such size that two of the elements will care for normal winter-time operation, one element for normal summer-time operation, leaving the third element available to care for unusual leakage, which cannot be immediately eliminated. All three elements are available for priming the circulating pump, and quickly establishing vacuum on the main condenser. The air lines from the bleeder heaters may be connected to the inter condenser shell, thereby relieving the duty on the primary jets and recovering a small amount of heat which would otherwise be wasted. The after condenser should be installed between the two bleeder heaters, thereby permitting of the maximum amount of bleeding to the low temperature heater.

The hotwell pump being a relatively inexpensive piece of equipment, may well be installed in duplicate. It should be driven by a wound rotor motor arranged for 20 per cent speed reduction.

The boiler feed pump need not be installed in duplicate. As now furnished by several manufacturers, it is a most reliable and satisfactory piece of equipment. Any repairs required, other than at the time of the annual overhauling of the main unit, will be minor and require only a relatively small outage, during which time the emergency feed pump may be used. The boiler feed pump may be driven by a squirrel cage motor and the feed line pressure controlled by a throttling regulator installed on the pump discharge. It is felt, however, that the additional cost of a wound rotor motor, with the necessary automatic control, will be more than offset by the saving in power and the increased ease of operation. When a variable speed motor is used, it should be arranged for a 20 per cent speed reduction. It is furthermore essential for satisfactory operation, that the feed pump have what is termed a drooping characteristic from no-load to full load; i. e., the head-capacity curve for all speeds must decrease with increase in capacity. If this is not the case, and there is a "hump" in the curve, there will be two capacities for a given head at any given speed, and the pump will be unstable, or "hunt," thereby causing unsatisfactory operation and the ultimate failure of the thrust bearing.

The forced and induced draft fans may be equipped with brush shifting polyphase motors or with wound rotor induction motors, either of which lends itself to automatic control. The first cost and maintenance charges will be much lower with the wound rotor motor, and if the average load on the boilers in service is fairly high, the efficiency will closely approach that of the brush shifting motor. The operating advantages in the writer's opinion, are so much in favor of the wound rotor motor that it is felt that it should be used for this service. A speed reduction of 50 to 60 per cent should be provided for, and should

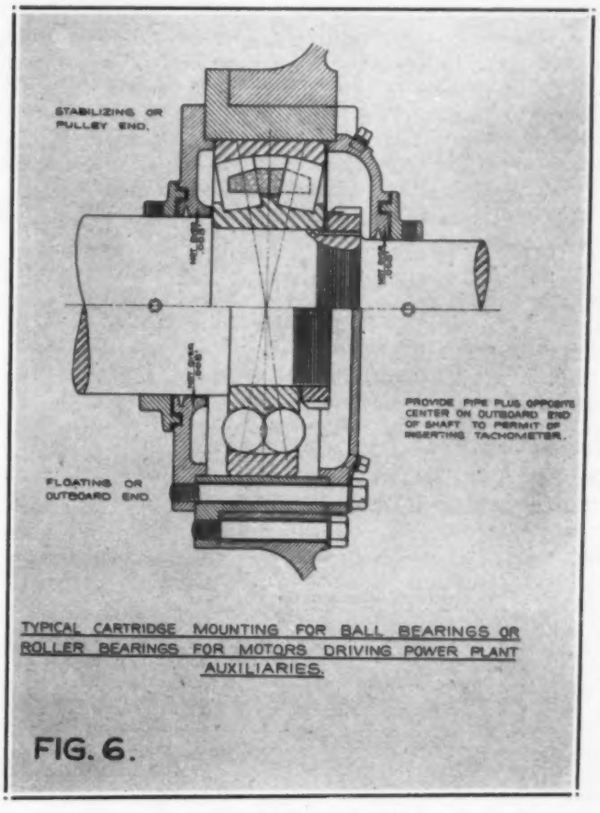

STABILIZING OR PULLEY END.
PROVIDE PIPE PLUG OPPOSITE CENTER ON OUTBOARD END OF SHAFT TO PERMIT OF INSERTING TACHOMETER.
FLOATING OR OUTBOARD END.
TYPICAL CARTRIDGE MOUNTING FOR BALL BEARINGS OR ROLLER BEARINGS FOR MOTORS DRIVING POWER PLANT AUXILIARIES.
FIG. 6.

FIG. 6

be arranged for automatic control, of which there are at least two makes on the market which will give very satisfactory service.

The stoker motors should be direct current, shunt wound and arranged for a speed variation of at least six to one, preferably by field control. The controllers should be so graded as to provide for equal increments in coal feed between individual steps on the controller, the total number of steps being approximately thirty in number.

It is felt that the insulation of all motors for power plant use should be so constructed as to be acid and moisture proof, and that all turbine auxiliary motors should be provided with splash proof housings, so that the failure of any of the piping, or the gland packing on a pump, will not result in the motor becoming soaked with water. Should the stoker, and clinker grinder, driving motors be installed on the boiler-room floor level, they should

be totally enclosed, preferably being fitted with Navy type frames and end-bells.

When motors of sufficient size, with suitable insulation, are used the question of motor outage reduces itself to the question of bearing failures. It has been the writer's experience that the failure of motor bearings can be practically eliminated by the use of self-aligning ball and roller type bearings. Where anti-friction bearings are used, it is essential that proper provision be made for excluding moisture and dirt from the bearings, as well as for keeping the lubricating medium within the bearing housings. The bearings should be self-aligning to preclude any possibility of their being distorted, due to too much tolerance in fabricating the motor, or to the presence of dirt or other foreign material in assembling. The bearing mounting of the cartridge type (Fig. 6), when equipped with labyrinth sealing rings, provides a water, oil and dust-tight mounting which will be entirely satisfactory when fitted with bearings having an ample factor of safety (the factor of safety should be not less than 12 and preferably higher on the basis of catalogue ratings).

As an example of the relative merits of sleeve and anti-friction type bearings, attention is called to a central station in the East, having somewhat in excess of 10,000 rated horsepower of motors on auxiliaries. Some 78 of the most troublesome motors, totaling in excess of 2,500 horsepower in sizes from 3 H.P. to 300 H P., both A.C. and D.C. types, have been replaced by motors fitted with anti-friction bearings of the type described above. To date there has been only one case of trouble caused by the chipping of one ball, which was picked up on routine inspection. Self-aligning roller bearings have been used on pumps up to 45,000 g.p.m. capacity with complete success.

In the course of a few years, data will be available on a new station, the first section of which is just going into service, which is equipped with self-aligning ball or roller bearings on all motors over one-quarter horsepower in size, while all of the condenser pumps are fitted with roller bearings.

There are methods of obtaining power for the essential auxiliaries other than the direct connected house alternator. One method that has gained considerable favor, is the spinning house turbo-alternator which is normally driven electrically with no steam passing through the turbine, but which will automatically pick up the essential load in the event of failure of the main bus voltage. This arrangement calls for additional capital investment in turbine, piping and transformers, while there is a definite operating loss. Another scheme that is being installed in one or more of the large base load stations, is to connect the auxiliary power transformers to the main generator leads and then insert a suitable reactance between this point and the main bus. This latter arrangement has the advantage of low first cost, but until it has been given the acid test of protracted service, does not seem to be as reliable nor nearly as desirable from an operating point of view as the direct-connected house generator, which scheme provides auxiliary power from the most efficient source, allowing at the same time full use of the regenerative cycle without any complication in wiring or switching. It has the further advantage of splitting up the the essential auxiliaries into groups or units centered about each main generating unit, thereby eliminating the necessity for long auxiliary power feeders. A maximum of reliability is provided for without any compromise in effciency, at a first cost that is as low, or lower, than any other scheme that has been adopted or suggested.

---

*The Selection and Maintenance of Oil Circuit Breakers**

By GEORGE A. BURNHAM†

THE object of this paper is to bring out for discussion certain of the major fundamental factors which should be given careful consideration in the selection of control and protective devices in heavy industrial service, in which may be properly classed the iron and steel industry.

Tonnage, apparently, is the watchword in your industry, and inasmuch as the oil circuit breaker controls and protects the machinery and motive power for steel production, it is of great importance that due care be exercised in the selection of the devices to perform this important function.

The inherent design features should not only meet the general requirements of ordinary industrial and central station service, but should also have ample provision to meet special conditions which may be imposed by the manufacturing process for which selection is made. For example, the cement and flour industry requires, in many instances, special constructional features; the chemical industry oftentimes requires special treatment of materials to resist the effect of destructive fumes; and the iron and steel industry requires special consideration, in many instances, particularly in view of the conducting dust deposited on insulating surfaces.

In the selection of the oil circuit breaker it is necessary first to study the proposed system on which the application is to be made, for the purpose of determining its electrical characteristics. These include the normal working voltage of the system, the continuous carrying capacity of the circuit in question. and the transient current and transient voltage con-

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

†Engineering Dept., Condit Electrical Manufacturing Co., Boston, Mass.

dition under various circuit combinations. From this may be determined the interrupting requirements, the momentary carrying capacity and the insulation specification.

Consideration should then be given to the work or "operating duty" required of the breaker—for instance, the number of circuit interruptions under normal working condition, which is determined by the processes of the industry; the circuit interruptions and reclosures under abnormal condition, such as short circuit, which are usually determined by the operating rules of the plant.

Thus far we have given consideration to the factors which determine, to a large extent, the physical dimensions of the oil circuit breaker unit, and at this point it is important to study the different design features of the oil circuit breakers offered by electrical manufacturing companies to serve the special requirements of the steel industry.

Selection should be made with reference to space requirements, arrangement of terminals, personal safety, fire hazard protection offered by inherent design, features tending toward continuity of service, etc., for it is these features, after all, which affect the cost of iron and steel indirectly through fixed charges, insurance rates and interrupted production.

In making a comparison of the design features, it is interesting to consider the destructive forces acting on the breaker parts such as the frame or top, tank, tank fastenings and insulators, which tend to destroy their co-operative relation, and then analyze the breaker design with these points in view.

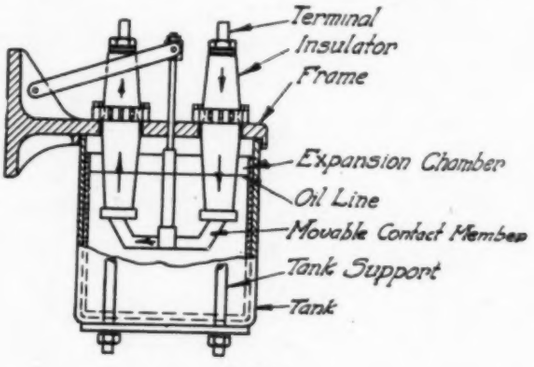


FIG. 1.

Fig. 1 shows the relation of parts in a breaker of ordinary construction.

These destructive forces may be divided into three classes, i. e., mechanical, chemical and electromagnetic.

Mechanical

Under the heading of mechanical forces may be included the effect of internal pressures due to circuit interruption, which exert both horizontal and vertical stresses.

At the instant the arcing contacts part, an electric arc is sprung, which displaces the oil. The rate of expansion and volume of gas generated depends, to a large extent, on the energy to be interrupted; the speed of circuit interruption; cooling effect of the oil, and the quality of oil used as an insulating medium.

This sudden expansion of the arc or gas bubble below the oil line produces a "hammer effect" on the sides and bottom of the oil tanks, the periodicity of which is at least equal to the natural perodicity of the electric circuit.

In this phenomena it is assumed that no explosion takes place, and it is the writers' opinion that the pressure wave is of such a shape that no part of the breaker except the tank is subjected to any great stress. These forces may be relatively great near the arc zone and may produce tank bulging in breakers having a high head of oil and relatively light tank construction. A "balanced head" of oil, that is, a tank design in which consideration is given the head of oil with reference to tank shape and thickness, will obviate any serious difficulty from this source of force at the point in question.

Chemical.

Forces due to ignition of chemical combination of gases thrown off during circuit interruption as above mentioned may be of great magnitude. Explosion, so called, may occur either below the oil line during circuit interruption or in the expansion chamber above the oil line during or after circuit interruption. They may occur in distinct sequence, one following the other as above, or, practically simultaneously, in which case the result of force may be tremendous.

When the electric circuit is interrupted under abnormal conditions, the action of the electric arc on the oil and arcing contacts causes volatilization, and gases are thrown off. Some of these gases, and particularly certain combinations, if ignited by an electric arc or pressure result in an explosion within the tank, the severity of which depends upon the volume of gas, kind of gas in combination, the proportion of combustible materials, and the shape of the pressure wave.

These gas bubbles are given off in the oil at approximately the level of the stationary contacts or slightly below and are carried up through the oil to the expansion chamber at the top, due to difference in the density of the gas and oil, or by upward pressure created by the arc disturbance.

If these gas bubbles are carried up through the oil in relatively small volumes entirely surrounded by oil, gases are chilled and reach the expansion chamber in a condition which will not tend to cause explosion. On the other hand, if the gas bubbles are extremely large, or if the gas bubbles follow in close proximity so that the small bubbles interconnect to form a large bubble, there is a possibility of the electric arc communicating through this gaseous path with the mixed gases in the expansion chamber to produce explosion above the oil line.

Explosions below the oil line produce the so-called "piston effect" by forcing the oil in a body against the breaker top or frame. It may be of sufficient magnitude to cause the oil and gases to be forced from the breaker, or may attain sufficient momentum to fracture breaker tops, insulator fastenings, or breaker mechanisms.

Explosions above the oil line in the expansion chamber are, in the opinion of the writer, the major cause of broken switch tops, ruptured tank fastenings and tank deformation of a nature greater than the usual tank bulging.

The pressure per square inch may easily reach 300 pounds and, therefore, in breakers with a tank diameter even as small as 20" the tank bolts and fastenings, tank and switch top must be capable of withstanding an impact of approximately 50 tons.

Electromagnetic

The construction of the average circuit breaker (see Fig. 1) consists of a supporting frame or switch top, which carries two insulators per pole, and these insulators in turn support the studs to which the terminal wires are fastened at the air end of the insulator. At the lower end of the insulators a contact block is mounted and so arranged that a movable bridging member makes contact, thus completing the electric circuit.

It is, therefore, obvious that the path of the current in the studs is in parallel planes and at right angles to the plane through the bridging member, thus forming a U-shaped circuit.

Such a condition causes electromagnetic stresses to be set up between the studs and certain reactions are set up in the bridging member due to the inter-linking of the magnetic field of the component conducting parts.

These forces tend to loosen the insulators in the clamping rings, move the studs in the insulators, and force the bridging member from contact with the stationary contact blocks, even though the breaker be in a closed position. Little, if any, difficulty is experienced below 30,000 amperes, but at the high current values, say 80,000 to 100,000 amperes, the construction and bracing of the main current carrying members must be extremely rugged to withstand these conditions, and the designer should use every effort to neutralize or balance these forces.

Inasmuch as the current which creates the magnetic field around the conductors is alternating, the resultant force is of a pulsating nature and of the same periodicity as the electric circuit.

Assuming that the average breaker requires one-tenth second from the time of short circuit to the parting of contacts, it is apparent that on a 60-cycle circuit the conducting parts of the breaker are subjected to 12 pulsating blows, the severity of which varies as the square of the current.

From the foregoing comments it is, therefore, apparent that when a circuit breaker functions under short-circuit conditions for a brief period of time, say, 1-10 to 1½ second, depending on the relay setting, the main conducting parts may be subjected to pulsating forces which vary from 12 to 180 strokes.

During this time, also, the current has reached values many times the rated continuous current carrying capacity of the circuit breaker, and as the heating varies with the square of the current, the temperature in the conductors reaches a very high value, bringing about expansion of parts, which, acting jointly with the electro-magnetic forces, places a tremendous strain on the conducting parts; then at the moment of contact separation the explosive forces within the tanks as aforementioned, bring the whole structure under tremendous momentary stress. In addition, during circuit interruption, the clearances under oil are reduced, due to the expansion of the conducting arc gases which are in contact with the conducting parts. This has a tendency to cause flashover, sometimes resulting in the electric arc burning the tank lining or even burning a hole in the tank itself.

It appears almost unbelievable that a circuit interrupting device could effectively disconnect 1,000,000 or 1,500,000 Kva under the above conditions without destruction. With proper design, however, it is possible to interrupt the circuit under these conditions a reasonable number of times with practically no deterioration except of arcing contacts and oil.

The foregoing gives a sort of mental picture of the forces and factors tending to deteriorate the breaker during the circuit interrupting period and in order that some fairly definite standard which might characterize satisfactory operation and good engineering be used as a basis of design and performance, the A. I. E. E. and the Electric Power Club have adopted standards. The standards are for design and performance and are representative of what is considered a proper balance of good, sound engineering on one side and economical expenditure on the other.

Briefly, these standards insofar as they apply to oil circuit breakers, may be classified as follows:

(1) TEMPERATURE, which includes the maximum temperature rise allowable under continuous operation at full rated load, and the carrying capacity under momentary conditions. The momentary carrying capacity also includes the effect of electro-magnetic stresses, and the limitation of momentary carrying capacity may be either a heating limitation or a mechanical limitation.

(2) INSULATION

(3) INTERRUPTING CAPACITY. The question of carrying capacity and insulation is fairly well defined and well understood. For several years, however, the question of interrupting capacity and its reference to ratings has claimed the attention of the various standardizing bodies, as it is one of the dominating features which determine size and cost of equipment. It is believed well in order to clarify certain matters pertaining to it to consider more or less in detail the design features of circuit breakers with reference to this important item.

Present-day standards define interrupting rating as follows:

(a) The interrupting rating of an oil circuit breaker is a rating based upon the highest r.m.s. current at normal voltage that a breaker can interrupt under the operating duty specified.

(b) The value of current shall be taken during the first half-cycle of the arc between contacts during the opening stroke.

Operating duty is defined as the specified number of unit-operating cycles at stated intervals. The unit-operating cycle consists of the closing of the circuit breaker, followed immediately by its opening without purposely delayed action.

Under performance in the standards, it defines that an oil circuit breaker shall interrupt circuits within its rating without emitting flame and after having performed its duty cycle on which its rating is based that the breaker shall be in the followig condition:

MECHANICAL: The breaker shall be substantially in the same mechanical condition as at the beginning.

ELECTRICAL: The breaker shall be capable of carrying rated voltage and its main current carrying

parts shall be substantially in the same condition as at the beginning. After performance at or near its interrupting capacity, the interrupting ability of the breaker may be materially reduced, and it is not to be inferred that it may be reclosed after such performance without inspection and, if necessary, making repairs.

The standard duty cycle on which published ratings are based consists of two unit-operating cycles at a two-minute interval, i. e., the breaker being in open position closes, opens, remains open for two minutes, closes again and then opens, and under these conditions if the breaker is opened at its full interrupting capacity or thereabouts, the rules state that the breaker should be inspected to see if there is any necessity for repairs. This is called the 2-OCO duty cycle. Ratings may be given for any number of combinations of circuit interruptions or intervals, and it is apparent that each combination would call for a different rating. Some of the more common combinations are given in the following tabulation, together

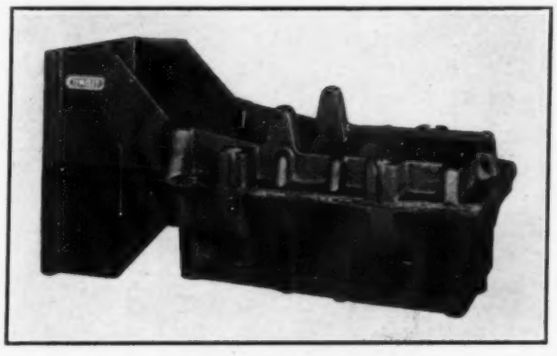


FIG. 2.

with the effect which these combinations have on the standard rating of the breaker:

2-OCO	2 minute interval	100%
4-OCO	2 minute interval	70%
4-OCO	30 second interval	60%
4-OCO	No time interval	30%
300-OCO	15 minute interval	30%

We now have set before us, briefly, the stresses incident to circuit interruption which tends to deteriorate the breaker. Then we have the performance standard which places the limitations on deterioration.

In a few words, therefore, a circuit breaker becomes a device in which tremendous internal pressures are set up incident to its operation, which it must withstand without destruction, and with this in view let us briefly consider certain fundamentals applicable to the average breaker construction.

The frame or switch top bears the same relation to a circuit breaker as the foundation does to a building. In the design, strength and rigidity of the frame or switch top effect satisfactory operation from the viewpoint of every single function which the breaker is called upon to perform. Strength in a breaker frame is not enough. The frame must be strong and in addition rigid, because a frame which is simply strong may readily yield but not break and such construction in a circuit breaker frame where the tremendous stresses have to be encountered, not only in circuit interruptions but the mechanical stresses that are brought about through toggle actions, have a tendency to cause the frame to spring. This affects the current carrying capacity because no permanency of adjustment may be obtained. It affects the momentary carrying capacity, particularly due to stresses of electro-magnetic nature, because insulators are fastened to the

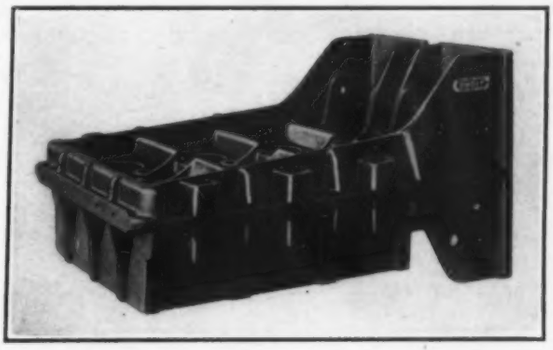


FIG. 3.

frame and the stresses are, therefore, carried back to this point.

During the circuit interruptions the internal pressures set up may be so great as to deflect the frame to a sufficient extent to bring mechanical strain on the insulators, mechanism and breaker structure. Such is not the case, however, if the breaker frame is designed with sufficient rigidity, and in the writer's opinion it is believed when dealing with such force, and particularly on account of the importance of the circuit breaker in the production schedule, that only the most rigid

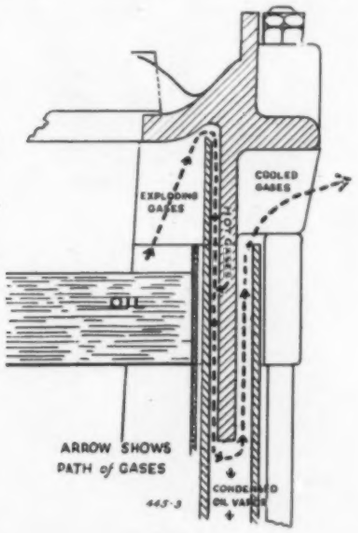


FIG. 4.

structure should be used on which to assemble the parts, which constitute the breaker and that cast frames, heavily ribbed, of rugged design, give the foundation to build on that which will result in satisfactory service without continuous adjustments and maintenance.

In brief, a circuit breaker is no better than the rigidity of its frame, and strength alone should not be considered except in connection with rigidity.

Figs. 2 and 3 show circuit breaker frames which have been designed with a very large factor of safety, particularly with a view of getting rigidity in construction.

Special attention has been given to the ribbing, its location and relation to the stresses set up during circuit interruptions. It is argued that resiliency is

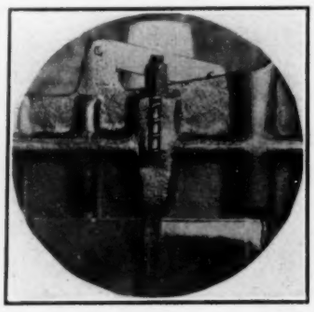


FIG. 5.

necessary to cushion impact and it is the opinion of the writer that resiliency interposed at the proper point in the design of the breaker can be used very effectively in resisting and reducing the forces transmitted to tanks, frames and tank bolts, but it is essential that it be interposed at some other place than in the frame itself.

Fig. 4 shows this feature of design, which has been very successful. This design is particularly adapted where a minimum of space is available, or where it is necessary to replace existing breakers of

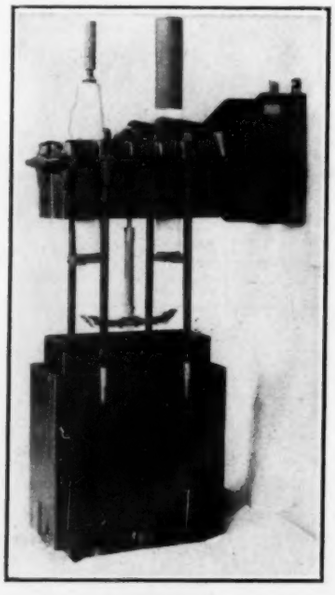


FIG. 6.

insufficient interrupting capacity due to growth of system. This design has a very rugged, rigid frame with a deep web extending below the oil line. This construction is for the purpose of reinforcing the tank at its open end in order that it may withstand horizontal stresses. The tank, it will be noted, is not fastened rigidly, as is the usual custom, to the frame, but is resiliently supported. (See Fig. 5). In other words, the tank can move slightly when an interruption causes the pressure within the tank to rise above a predetermined value. As the tank moves, energy is absorbed and the tank fastenings and their connections to the frame of the breaker are not called upon to withstand the tremendous stresses which would have been the case had the tanks been fastened rigidly to the frame. The tank movement automatically vents the breaker. This allows the gases to be forced out of the orifice of relatively large area and to expand into an outer chamber or spill tank. Here the oil vapors are condensed and separated, the gases going to the atmosphere and the oil being retained at the bottom of the spill tank.

Figs. 6 and 7 show tanks embodying these features.

The double tank construction affords the following features:

It serves as an auxiliary expansion chamber and provides an efficient means for chilling of the gases

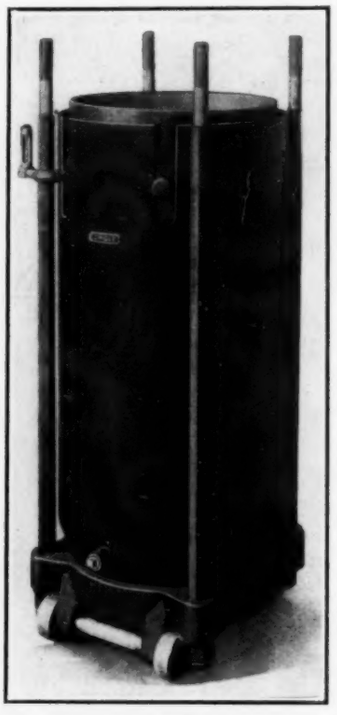


FIG. 7.

which reach the main expansion chamber before they are distributed to the surrounding atmosphere. It confines any burning vapors or oil in a deep, narrow, restricted chamber in such a manner that the tendency to combustion is minimized. It safeguards life and property should a hole be burned through the inner tank; in fact, this construction tends to prevent the starting of oil fires. In this respect, it is much more effective than breakers without the double tank features, but surrounded by the usual concrete cell or barrier construction. No added space is required and practically double strength is provided in the tank walls. The added cost is negligible compared to the worth-while benefits which are obtained from the viewpoint of safety to persons and property, in addition to effectively safeguarding continuity of service.

In selecting circuit breakers, particular attention should be given to the speed of circuit interruption as it affects the volume of gas generated, which is one factor which determines tank pressures.

Fig. 8 shows an effective high-speed contact arrangement employing the use of multi-break con-

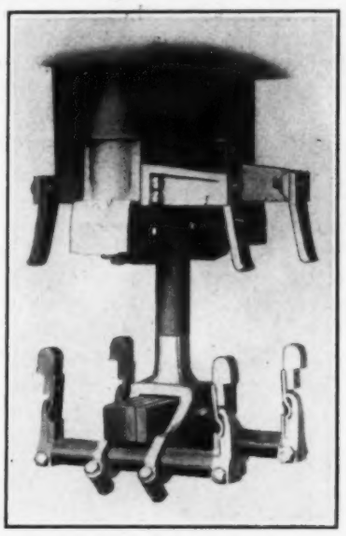


FIG. 8.

struction. Average speed as high as 25′ to 35′ per second may be obtained without causing the contact members or switch mechanism to be accelerated more than 5′ per second. This construction allows reasonable mechanical speeds with maximum speed of circuit interruption, and reduces the mechanical shocks to a minimum. The location of the arcing contact with reference to the main contacts and insulators affords a free and unobstructed path for the gases to the expansion chamber. The arcing contacts are so arranged that a powerful magnetic action is obtained during circuit interruption, which materially increases its effectiveness in circuit interruption.

Selection as Affected by Maintenance

Probably no group of engineers and operators places quite so much emphasis on maintenance as those of the iron and steel industry. Realizing the importance of minimizing the length of time necessary for inspection and repairs is the aim of circuit

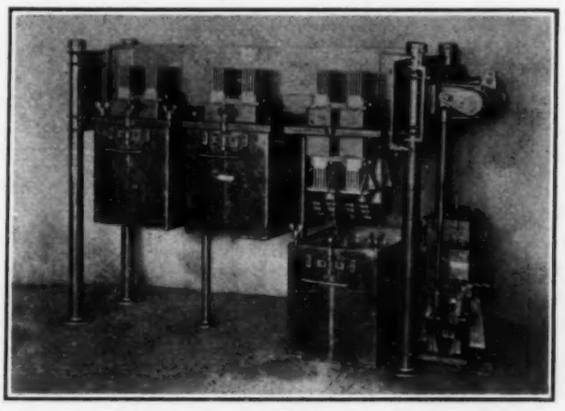


FIG. 9.

breaker design to provide means whereby inspection and repairs, if necessary, can be easily and quickly facilitated.

Opinion is about equally divided among operators regarding the merits of the removable-tank type breaker such as shown in Figs. 9 and 13 as compared to the removable-truck type breaker as shown in Fig. 10. Each has certain advantages, depending

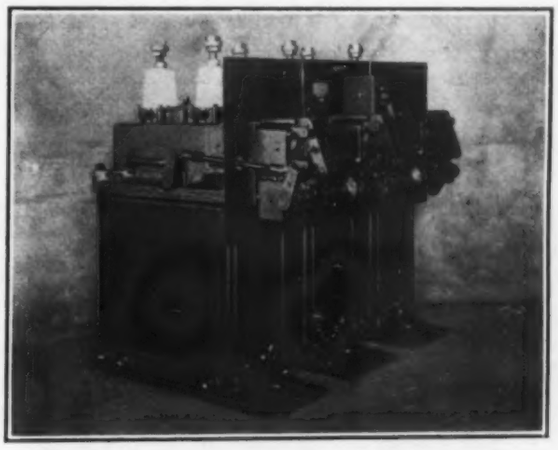


FIG. 10.

upon the station construction and arrangement employed. All manufacturers now carry these two types in the moderate and high interrupting capacity classes.

On the question of inspection and adjustment of contacts only, there is really little difference in the time consumed if tank-lifting facilities are provided for the removable-tank type of breaker. However,

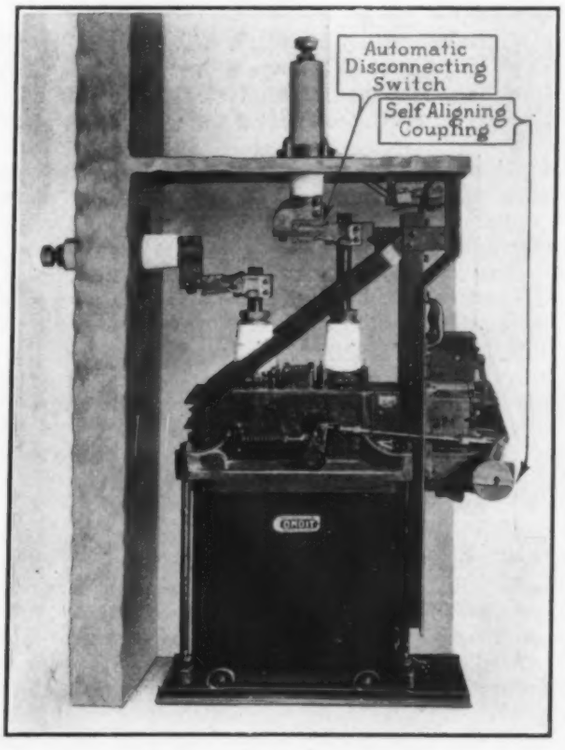


FIG. 11.

if much repair work is necessary, the removable unit type offers many advantages, both as to time and ease of repair. The automatic disconnective switch and self-aligning switch couplings shown in Fig. 11 allow a switch unit to be replaced in a few moments without the use of tools, and in certain manufacturing processes this feature has a decided bearing on the selection of type.

The removable-unit type of breaker has a decided advantage from the viewpoint of cubit foot per am-

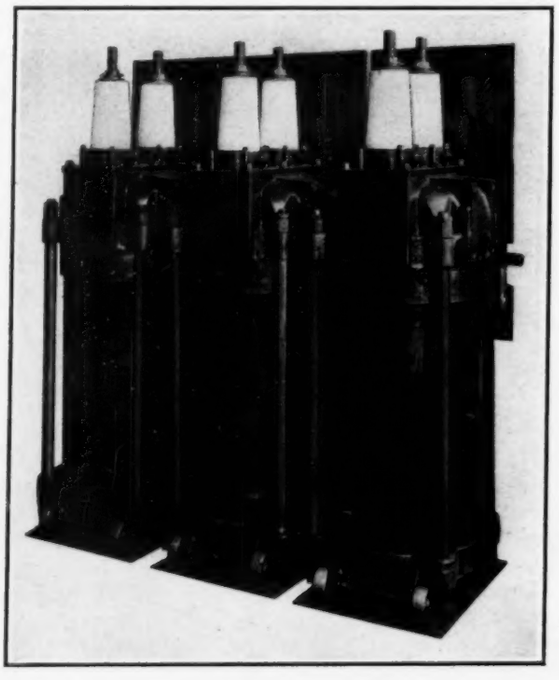


FIG. 12.

pere of interrupting capacity. Ten years ago the average cubic foot per ampere interrupting capacity for popular removable tank type 15,000 volt moderate interrupting capacity devices was approximately .01. Today it is approximately .003. This has been brought about by a better understanding of the phenomena of circuit interruption, by utilizing material of greater strength, use of designs which offer greater resistances to internal pressures by suitably shaping and ribbing of circuit breaker tops, etc., together with much heavier tank construction and tank fastening than had heretofore been employed.

Figs. 6 and 12 show breakers in which the interrupting capacity is increased by the use of self-contained mufflers or venting schemes combined with energy absorption devices similar to those so effectively used in taking care of recoil in gun carriages and are particularly adapted where a minimum of space is available.

The removable-truck type breaker utilizes the entire cell space to advantage, i. e., the cell space is entirely available for the circuit breaker, whereas in the removable-tank breaker approximately 30% of the cell space is reserved for tank removal and is only employed for the purpose it is intended for a few moments during inspection or repair period. In certain localities and under certain conditions, this space is very valuable, but it is obvious that by referring to Figs. 11, 12 and 14 the removable-truck type breaker effectively utilizes all the space and has in the majority of instances a relative space factor as low as approximately .001.

It is interesting to note these approximate figures, as they indicate that it is possible to increase the interrupting capacity of the older installations about 8 times without tearing down cell structure, bus compartments, etc. The present-day breakers also have a very much larger factor of safety for insulation and, therefore, the replacement of existing breakers not only provides increased interrupting capacity, but also materially increases the factor of safety of a system from the viewpoint of insulation.

It hardly seems necessary to comment on the use of the air circuit breaker on systems of moderate or high interrupting capacity, or on moderate voltages where the energy necessarily has to be interrupted in a restricted space. However, where economic conditions permit, it is used on low-voltage alternating-current circuits of low interrupting capacities.

Considering, once more, oil circuit breaker designs, the research and engineering departments of

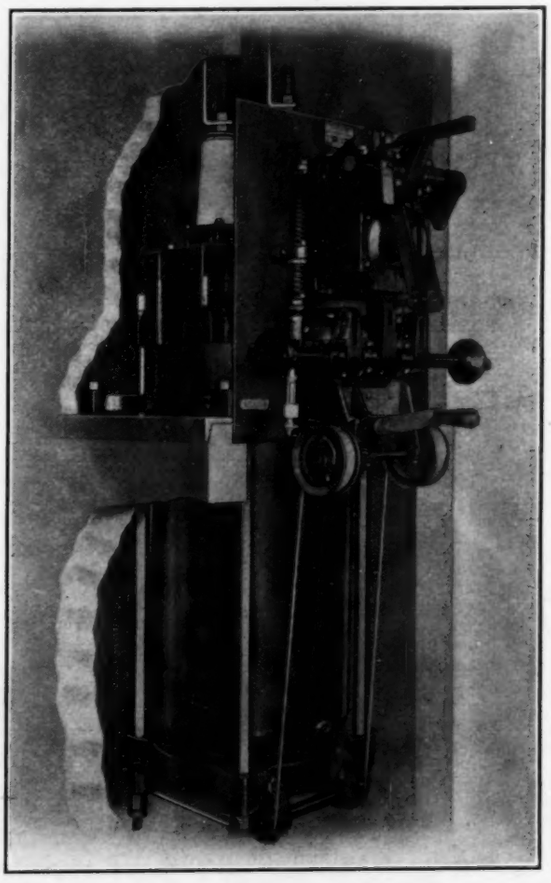


FIG. 13.

the various manufacturing companies are bending every effort to produce devices which will have a maximum interrupting capacity and require a minimum amount of space.

While the first cost of circuit breakers is of utmost importance, the overall cost of that part of the contemplated installation which is determined by the space requirements of the breaker is the de-

termining factor from an economic point of view. This is, indeed, of greater importance when considering replacement of existing breakers. Here not

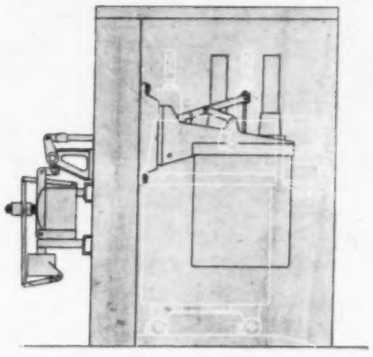


FIG. 14.

only minimum space, but particularly the width of the breaker is usually the determining factor in the cost of contemplated changes, for it is usually the width of the breaker which determines, after all, whether or not extensive modifications are necessary in cell structure, buss arrangements and building extensions.

With improved and more efficient devices built to stand harder service conditions, which arise as the power capacity is increased, will come less service interruption, better production, and possibilities of lower maintenance.

Circuit breaker manufacturers appreciate their problems, their duty to the industry, and the important part which the switching equipment plays in the successful control of the increasing power demands. Conservative designs, with higher factors of safety, both mechanically and electrically, will tend to minimize service interruptions and maintenance charges, without adding materially to the installation cost. Already considerable progress has been made in keeping down the space requirements of oil circuit breakers and, with contemplated designs, it is believed that future development along this line will materially reduce the capital expenditures of circuit breaker installations as a whole.

---

*Extending the Heat Cycle in Boiler Rooms by the Use of Preheated Air for Combustion Purposes**

By JOSEPH G. WORKER†

ONE of the outstanding achievements in fuel burning equipment is the use of preheated air for combustion purposes. Here lies the ultimate opportunity for extending the heat cycle in boiler plants far beyond the limits of anything heretofore accomplished. Attempted theories concerning heat interchangers and vacuum economizers have at times in the past nourished the hope that a boiler cycle could be evolved which would have the opportunity of absorbing all the heat in the gases down to the theoretical temperature of the air in which the phenomena took place. Results already accomplished with air preheaters point the way in the near future to accomplish this result in a simple and practical way. Not only is there a direct benefit due to the heat recovery from the waste gases but an indirect benefit of very substantial proportions is secured by this simple process. Combustion processes and fuel bed conditions are markedly improving. Less air is required to support the processes of combustion, and more uniform fuel bed conditions are attained. It is easier to burn coals which are sensitive to smoke, entirely without smoke.

It will not be attempted in this paper to record test results of individual boiler plants that are using preheated air but rather to point out some of the elements that require consideration in the design of a modern preheater stoker plant.

Sufficient data has now been obtained to design with every degree of certainty the performance that can be expected from a preheater stoker installation.

It is necessary, however, to fix certain proportions for each individual installation, and it is necessary to design certain parts of the stoker for use with preheated air.

Cost of Preheated Air

There is a certain amount of waste heat from flue gases that can be obtained at a low cost. If we attempted to preheat the air for combustion purposes to say 100° F. this preheat could be obtained without much additional expense for handling the hotter gases, and the cost for preheated air equipment would be small. Such an installation could also be made without complicated and bulky equipment. The first 100° F. of preheated air is without question the most effective, and the least expensive. Care must be taken in the consideration of each individual situation to determine whether or not high preheated air will pay for itself. Some engineers are of the opinion that you should obtain as high a temperature of the gases, to be used for combustion, as possible. The point that is desired to emphasize here, however, is that even though a particular situation might not warrant very high heating of the combustion air, it does not follow that low temperature preheating will not pay and be very ef-

*To be presented at Twentieth Annual Convention, September 14th to 19th, 1925.

†Vice Pres., American Engineering Co., Philadelphia, Pa.

fective for combustion purposes. A large number of boiler plants in the United States are already using effectively low preheated air, and considering the small cost to obtain this, they no doubt are showing overall results that warrant the installations.

Types of Air Preheaters

Quite a number of designs of air preheaters are now coming into general use. Most of them come within one of the following three types:

(a) The Plate preheater.
(b) The Tubular preheater.
(c) The Rotary air and gas preheater.

The Plate type preheater, a typical example of which is shown in figure No. 1, is built with a number of flat steel plates of small gauge. These plates are set side by side about 1¼" apart. The gases are taken from the flues and passed between every other plate. The air to be used for combustion purposes has a counter flow to the gases, between the alternating plates. In this way the heat is transferred from the metallic surfaces of the plates to the air. The preheater is baffled so as to provide for maximum absorption of heat.

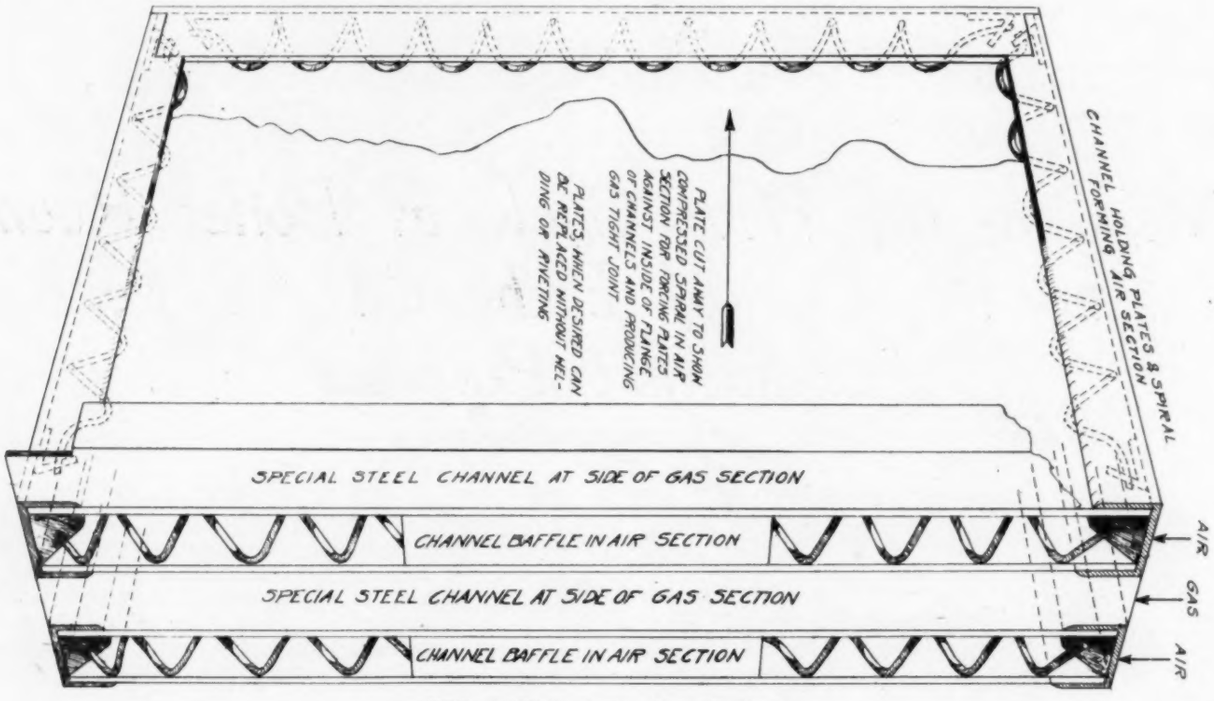

PLATES, WHEN DESIRED CAN BE REPLACED WITHOUT WELDING OR RIVETING
PLATE CUT AWAY TO SHOW COMPRESSED SPIRAL IN AIR SECTION FOR FORCING PLATES AGAINST INSIDE OF FLANGE OF CHANNELS AND PRODUCING GAS TIGHT JOINT
CHANNEL HOLDING PLATES & SPIRAL FORMING AIR SECTION
SPECIAL STEEL CHANNEL AT SIDE OF GAS SECTION
CHANNEL BAFFLE IN AIR SECTION
SPECIAL STEEL CHANNEL AT SIDE OF GAS SECTION
CHANNEL BAFFLE IN AIR SECTION
AIR
GAS
AIR

FIG. 1—Plate type air preheater.

The tubular type of preheater is shown in figure No. 2. It is built up with a number of vertical steel tubes, similar to boiler tubes. The gases from the flues are directed by air ducts to and through these tubes. The air for combustion is directed around the tubes and in this way, absorbs the heat from the metallic surfaces of the tubes.

A somewhat different idea in preheaters is shown in figure No. 3. The gases from the flues are directed to the preheater structure. By mechanical means, metallic surfaces with rotary motion, laternately pass from the zone of hot flue gases to the zone of combustion air. The air is confined to one side of the partition and passes downward through the porous cylindrical drum to a similar semi-circular chamber in the lower part of the housing. The gases from the boiler pass in the reverse direction, entering the lower chamber, passing upward through the rotor to the upper chamber. From here they are exhausted by a fan to the stack.

The rotor is kept in a state of continual slow rotation, so that the part heated by the flue gases is continually passing to the other side of the device, and gives up its heat to the cold air sweeping through it. The cold part of the rotor is continually returning to be reheated by the flue gases.

Care of Preheaters

Certain elements in connection with the use of preheaters must be given careful consideration in their operation. In all types of preheaters, there is a deposit of soot or tarry matter on the metallic surfaces which retards heat transference.

The cleaning of preheaters and the number of times a preheater should be cleaned depends largely on the operating conditions of the plant. It also depends upon the grade and character of the coal that is being burned. In some plants, every thirty days, the preheaters are taken off and the accumulation of soot in the tubes blown out with compressed air. This thoroughly removes any foreign particles that have been adhering to the exposed metallic surfaces.

Fluctuating loads on boilers and banking of boilers increases the possibility of hard soot accumulation in preheaters. In some instances serious clogging of the air passages occur, and means must be provided to clean out this hard scale; and operating conditions watched to prevent a recurrence of combinations of moisture in preheaters and soot.

The hard soot accumulation in preheaters is due to moisture in connection with the carbonaceous soot. This moisture comes to the preheater during banked periods when the relative temperature of gases and air creates a condition where dew is formed.

Some coals give off different carbonaceous gases and these have an effect on the metallic surface of air preheaters. This trouble extends to pitting of tubes and plates. Each set of conditions must be carefully analyzed in order to find out what character of operation and cleaning is necessary to overcome the difficulty.

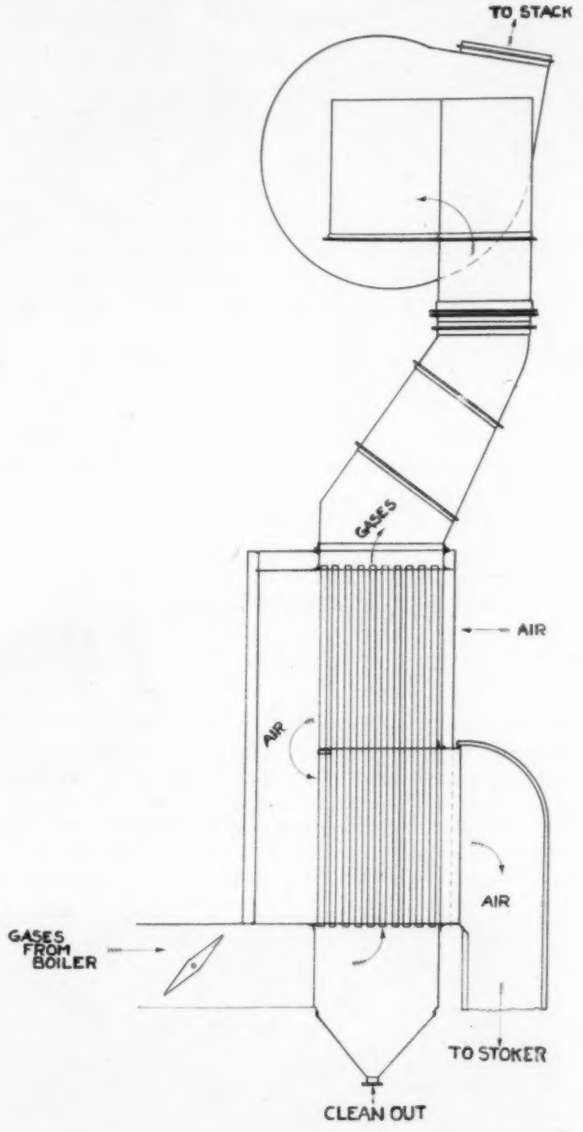


FIG. 2—Tubular type air preheater.

The design and construction of air ducts leading from air preheaters to the stoker must be given more consideration than the former usual method of cold air duct design. These ducts must be air tight because the leakage of highly preheated air is more undesirable than the leakage of cold air. All high temperature air ducts must be insulated, a typical method being shown in figure No. 4. It should be noted that this method consists of a layer of asbestos cement, then the use of blocks of magnesia and an outer covering of canvas.

The expansion of hot air ducts is another element of design that must be given careful consideration. By referring to figure No. 4, it will be noted that expansion joints are provided. The detail design of these expansion joints, of course, depends upon the length of the air duct and the character of its course, but in any hot air duct, very careful consideration must be given to this particular element of expansion.

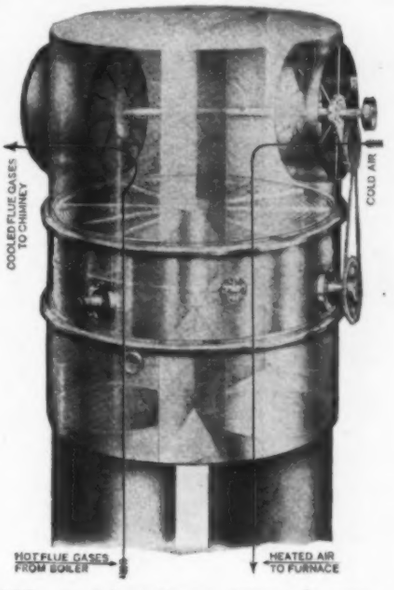


FIG. 3—Ljungstrom type air preheater.

Types of Furnace Walls

It has been found in combustion work that certain elements that have contributed largely to the thermal efficiency of fuel burning have brought into use structural features of furnace design that are rapidly coming into general use. This has led to a furnace wall design that has embodied in it certain features for reduction of radiation losses. There are at the present

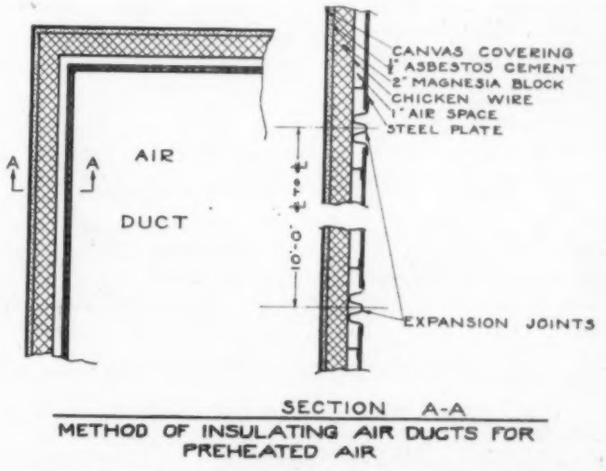
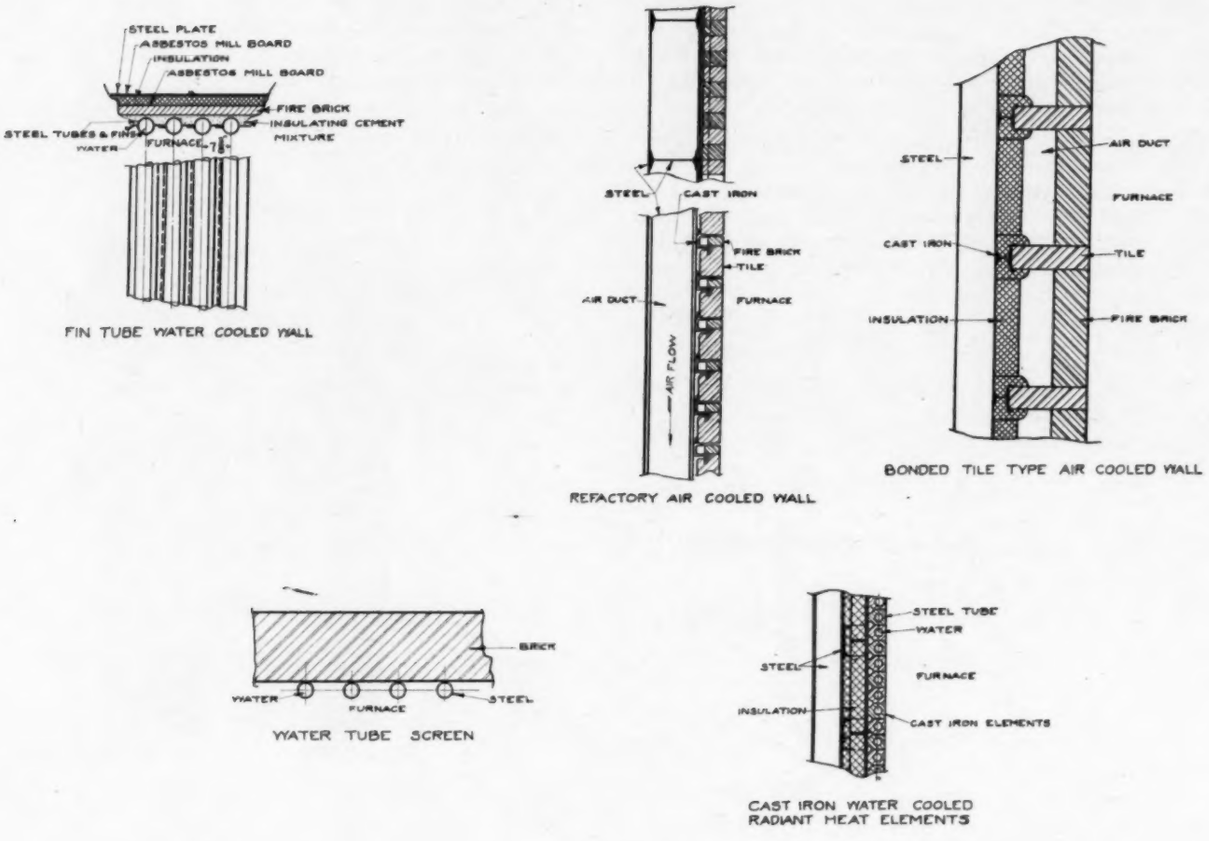


FIG. 4—Method for insulating preheated aid ducts.



TYPES OF FURNACE WALL CONSTRUCTION

FIG. 5—View showing different types of furnaces wall construction.

time a variety of opinions as to the relative merits of these wall designs.

Figure No. 5 shows several forms of furnace walls that are now being used in connection with steam boiler furnaces. These walls can be grouped in four classes, as follows:

(a) Water-tube-screen
(b) Finn tube water wall
(c) Refractory and air duct wall
(d) Combination of water tube and refractory

All of these types are in actual service in one plant or another, but for a particular set of conditions careful consideration should be given as to the one that would best serve the local coal and operating conditions.

The Modern Underfeed Stoker Using Preheated Air

The modern underfeed stoker (Figure No. 6 and No. 7), has embodied in it certain features of design, which primarily consists of a long travel of coal at high velocities and with a corresponding proper proportioning of air velocity. An analysis of hundreds of tests conducted for research purposes show the reason for heat losses contributed to the stoker proper.

It will be remembered that it was only a few years ago that a stoker was installed under the front portion of the boiler. It has only been recently that installations have been going under the entire boiler. In the design of the modern stoker each element that had to do with any of the thermal losses went through a vast amount of research and testing in order to determine just what was necessary to reduce these losses. For example, all tests and data con-

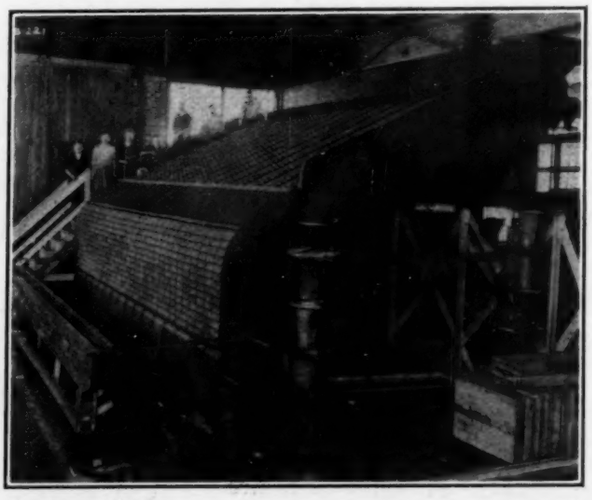


FIG. 6—View showing wedge shape pushers in bottom of retort modern underfeed stoker.

cerning that part of the stoker used for the burning of the refuse was collected and analyzed carefully to determine the proper proportions that would bring about a reduction in the combustible in the refuse. It will be noted by referring to Figure No. 8 the changes that have undergone in this refuse burning part of the stoker. In older designs it was

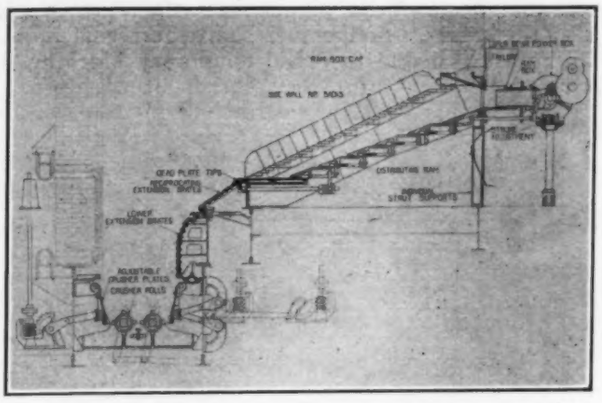


FIG. 7—View showing modern underfeed stoker for preheated air.

the practice in many plants to use water in connection with the ash discharge mechanism, for quenching the refuse. This, of course, increased the carbon loss. By continuing work along this line, it was finally established that with proper proportions for the grate surface, that would be required for a particular installation, this loss could be definitely established and later was followed by actual installations which gave confirming results even better than former development work revealed.

The fuel supporting surface of the stoker has also gone through a complete re-design. Where formerly single individual pushers in a retort were used, now the entire bottom of the retort gives a wedge-shaped movement and a definite control and distribution of the fuel. This change in design has reduced the excess air required for combustion in a particular zone of the fuel bed, with the result that in almost every case of recent installations, higher CO^2 performance is obtained than was possible with the former and older contour of fuel bed.

Character of Fuel Bed—Modern Underfeed Stoker With Preheated Air

The fuel bed of the modern underfeed stoker has undergone a more definite and positive change than is generally appreciated. Figure No. 9 shows an outline of an underfeed fuel bed with a stoker structure that is installed completely under the boiler. For reference convenience, the fuel bed has been divided up into four zones:

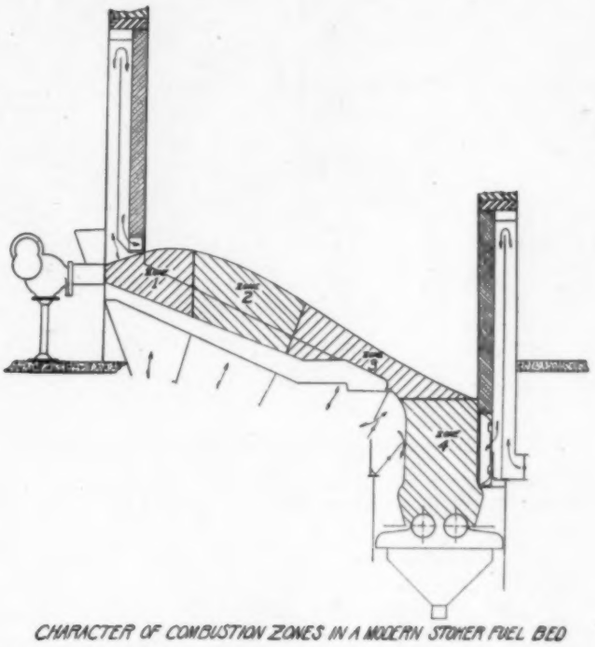


FIG. 9—View showing different zones of a modern underfeed fuel bed.

Zone 1. Where the fuel enters the furnace, moisture is evaporated and the volatiles are distilled.

Zone 2. Where partially coked fuel and carbon is burned.

Zone 3. Where almost complete carbon is burned.

Zone 4. Where the refuse is burned.

With the use of preheated air, Zone No. 1 shows more changes in character than any other portion of the fuel bed. It is at this point where the volatile gases are distilled, and it is the most critical portion of the fuel bed on this account, for the

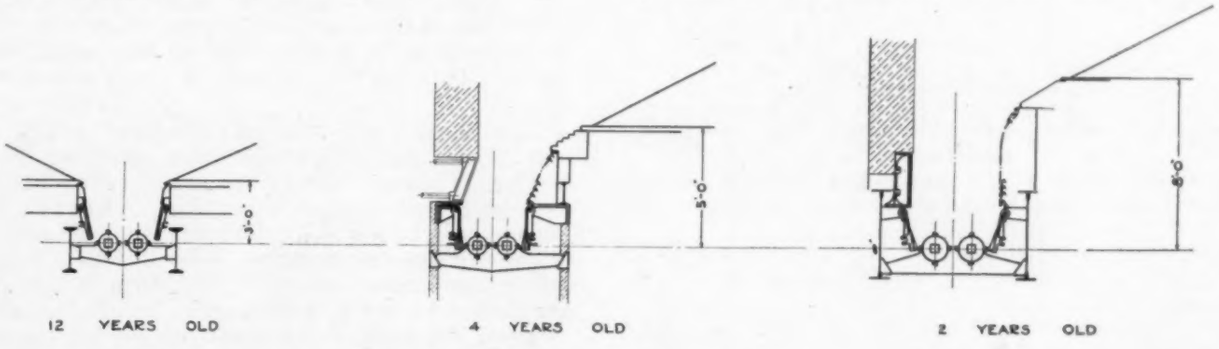
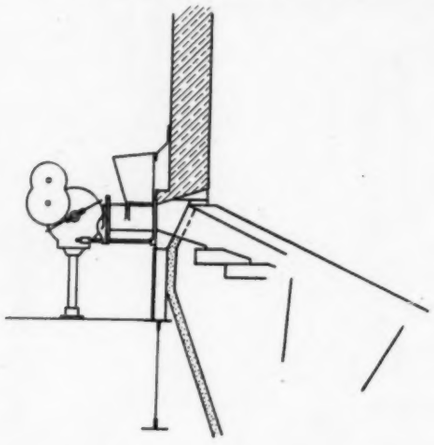

12 YEARS OLD
4 YEARS OLD
2 YEARS OLD
OLD AND MODERN UNDERFEED DESIGN FOR REFUSE BURNING
STRUCTURE OF STOKER SHOWING RELATIVE PROPORTIONS

FIG. 8—View showing development of refuse burning portion of stoker.

obvious reason that the gases, unless all conditions are favorable, can easily escape unburned.

It is at this point where the moisture in the coal is evaporated. If preheated air is supplied at a temperature of 600°F, the heat in the air is sufficient to dry the coal with ten per cent moisture by the time it is 6″ from the front wall, even though no heat is obtained from the furnace itself. Preheated



VIEW SHOWING METHOD OF INSULATING STOKER AIR CHAMBER

FIG. 10—Method of insulating air ducts immediately under stoker when high temperature air is used.

air in effect lengthens the stoker fuel bed for the reason that it decreases the amount of space required for drying the coal and makes more effective the actual carbon burning zone.

In observing a preheated air fire, there is a very intense incandescent appearance to the fuel bed in Zone No. 1. There is also a more pronounced caking effect in the fuel bed at this point. The amount of moisture that must be evaporated at the entrance of a fuel bed is a tremendous amount. On some

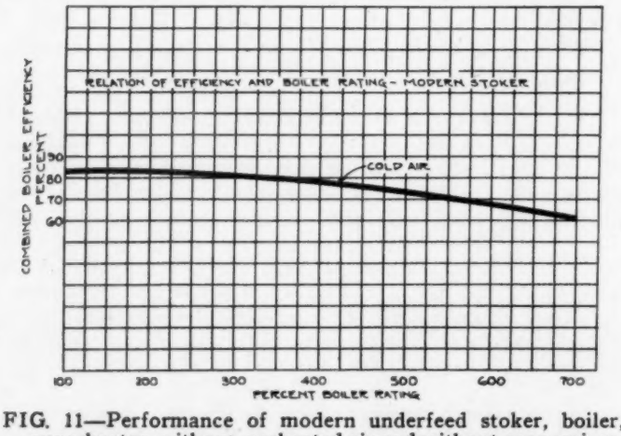


FIG. 11—Performance of modern underfeed stoker, boiler, superheater without preheated air and without economizer.

of the large stokers that are now being installed, there is from four to five tons of water that must be evaporated in Zone No. 1 per hour.

The efficiency of Zone No. 1, therefore, has increased tremendously over the efficiency of a similar zone in older stoker operation.

Zone No. 2 has not increased in efficiency as much as Zone No. 1, although there has been a change in the character of this portion of the fuel bed. With highly preheated air entering this zone under the fuel bed, a higher proportion of CO in the lower portions of the fuel bed, subsequently converted to CO^2, gives considerably more volume of gases of high CO^2 above this portion of the fuel bed.

Preheated air has influenced Zone No. 3 more in actual operation than thermal results. In daily operation, it has been found that when using cold air at this portion of the fuel bed, where coal mixed with refuse is liable to cause temporary blocking of the progress of the fuel bed, it has been shown in actual operation that by the introduction of highly heated air in this zone, after giving sufficient time for the heated air to have its effect, this portion of the fuel bed will start moving and give no further

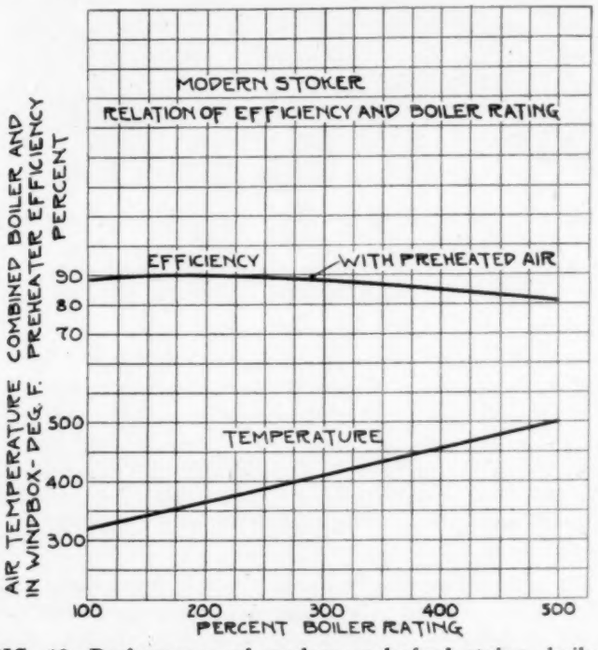


FIG. 12—Performance of modern underfeed stoker, boiler, superheater, and with air preheated up to 500°F.

trouble with blocking. The reason for this is due to maintaining a more even temperature of the ash particles that causes clinker.

The residue from combustion found in Zone No. 4 is difficult to burn under any condition, so that the introduction of preheated air in this portion of the stoker has had a beneficial definite effect in the handling of the ashes and burning out the carbon in the refuse. This burning process is much slower than formerly.

The physical structure of the refuse burning portion of the stoker has had more effect in the reduction of carbon losses than the introduction of preheated air. A few years ago, these ash wells were comparatively wide and narrow. Others were of entirely different volumetric dimensions. Considerable research work was done to determine the proper application of air to this portion of the stoker. In some of the older designs, corners of the ash wells were found where no air was admitted to the refuse at all. Through a process of changing proportions and design of parts, the modern structure as shown in Figure No. 8 has been evolved. On

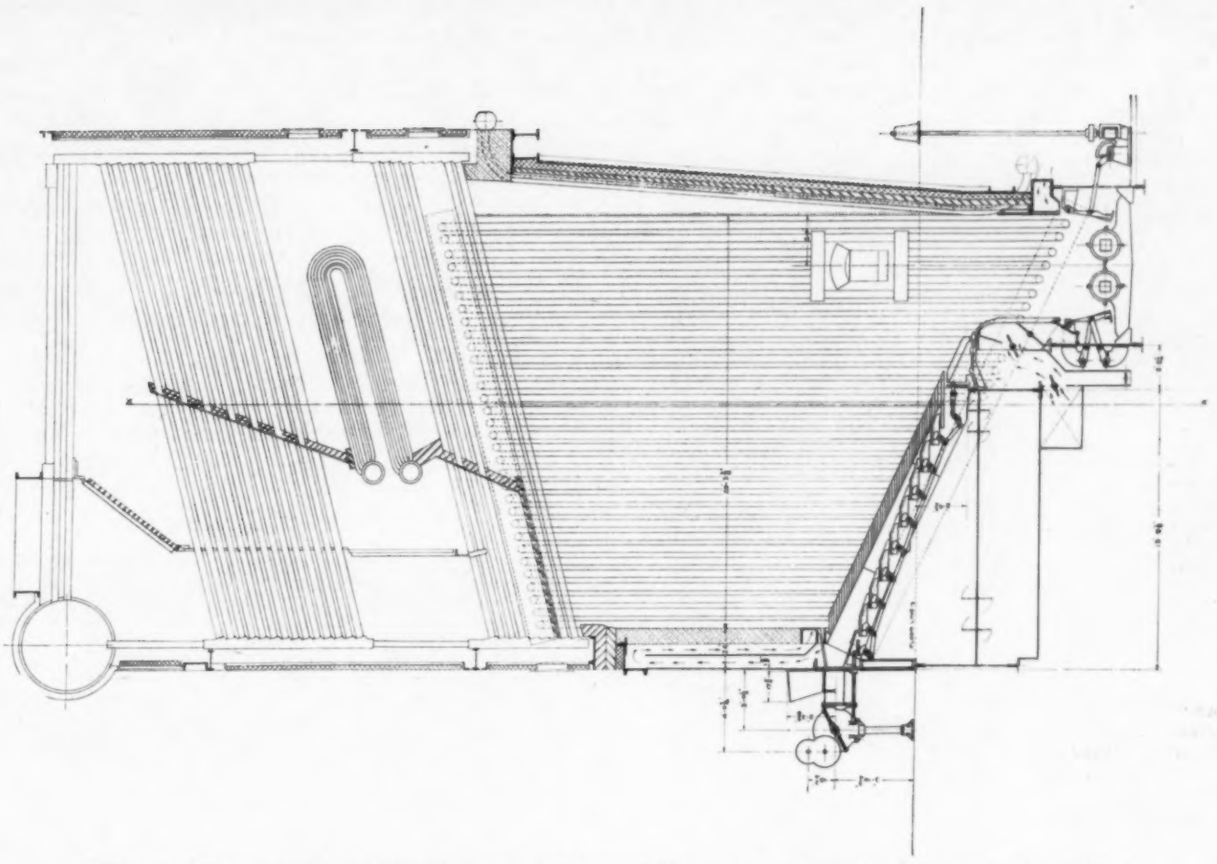


FIG. 13—View showing application of modern underfeed stoker to horizontal water tube boiler.

account of the testing and experimental work done in this portion of the stoker, it is now possible to know definitely the loss that will come through burning out the refuse for different kinds of coal and different operating conditions.

When highly preheated air is used, for example it is proven good practice to keep the crusher rolls in slow rotation continuously. With some Eastern coals, only one of the two crusher rolls is kept in motion, bringing in the other roll when necessary to lower the height of ashes towards the bridge wall.

The ashes in the ash pit are allowed to accumulate to a level to which the fuel bed is carried on the lower Zone No. 3 of the fuel bed, so that the contour of the lower section of the fuel bed falls closely to the angle of the fuel bed on the extension grate.

Insulation of Stoker for Preheated Air

One element that has required consideration in connection with the use of preheated air with underfeed stokers is the insulation of the stoker and ducts immediately under the stokers. One method of insulating the wind chamber is shown in Figure No. 10, where the air duct structure is carried well under the stoker. In effect, this leaves an air space between the air duct and the stoker front structure. The entire front of a preheated stoker is cool and no difficulty has been experienced after proper insulation with any of the front operating parts of the stoker.

Performance of Modern Underfeed Stoker With and Without Preheated Air

In order to give some idea of the performance of a stoker embodying all of the elements of modern design, curve, Fig. 11 has been prepared showing the thermal efficiency at different boiler ratings. It will be noted that 83% efficiency is obtained at 200% of boiler rating. The curve is flat, resulting in 74% efficiency at 500% of boiler rating.

Figure No. 12 shows the performance of this same stoker when using combustion air heated to 500°; 90% efficiency is obtained at 200% of boiler

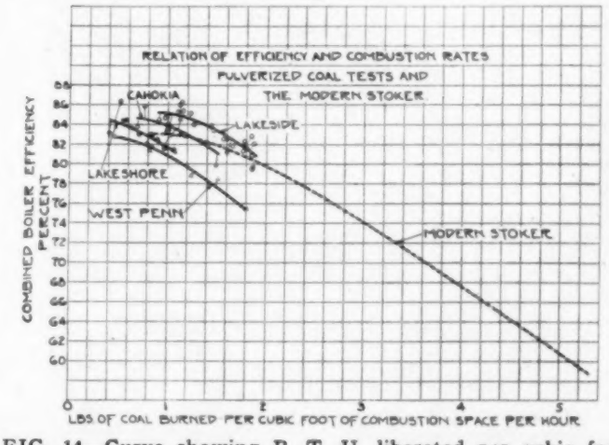


FIG. 14—Curve showing B. T. U. liberated per cubic foot of combusion space per hour with modern underfeed stoker.

rating and 82% at 500% of boiler rating. These efficiencies are of a modern boiler and superheater, but no economizer.

Figure No. 13 shows the application of the modern underfeed stoker to a modern steam boiler. In order to give an idea of the B.T.U. liberated per cubic foot of furnace volume, Figure No. 14 has been prepared. By referring to table No. 1 it will be noted that the Hell Gate setting has burned 86,700 B.T.U. cubic feet per hour on test, and this table also shows the B.T.U. liberated in the design of some of the more recent pulverized coal and stoker stations.

3. The modern stoker can be operated at 500% boiler rating continuously.

4. The modern stoker can be operated to handle peaks of short duration up to 700% boiler rating.

5. The CO^2 performance with preheated air will range from 15½% to 250% boiler rating to 16½% at 350% rating and above.

6. Combustible loss in refuse will be less than .7 of 1% of B.T.U. in coal or 7% combustible in refuse.

7. 80,000 B.T.U. for maximum rating can be liberated per cubic foot of furnace volume per hour.

STOKER STATIONS

Station	Rated H.P.	Comb. Space Cu. Ft.	Cu. Ft. per Rated H.P.	Lbs. Coal Per. Cu. Ft. Per. Hr.	B.T.U. Per Cu. Ft. Per. Hr.	B.T.U. Per. Lb. of Coal
Delaware	1508	7300	4.85	2.23	30,800	13800
Hell Gate	1590	6700	4.22	6.2	86,700	14000
Kearney	2360	10200	4.32	2.73	36,300	13300
Weymouth	1974	10430	5.28	2.25	32,100	14250
Zilwaukee	928	5600	6.03	3.28	45,600	13900
Interboro	1140	2910	2.53	6.	81,000	13500
Chester	1422	7300	5.18	2.1	29,100	13800
Saxton	1100	5200	4.73	3.75	50,500	13500
PULVERIZED COAL STATIONS						
Cahokia	1801	11440	6.36	1.47	19,340	13161
Colfax	2768	17350	6.27	0.91	12,050	13237
Trenton Channel	2910	24200	6.19	1.71	22,600	13200
West Penn	1533	12400	8.08	1.84	24,800	13500
Milwaukee (Lakeside)	1305	6073	4.67	1.88	23,050	12272
Cleveland (Lake Shore)	3060	26000	8.50	1.06	13,500	12717
Peoria	1392	16100	11.55	1.0	10,000	10000

It might be well to summarize briefly the advantages afforded by the application of preheated air to stoker operation.

1. The efficiency of the modern stoker and boiler and superheater at 200% boiler rating will be 83%.

2. The efficiency of the modern stoker, boiler, superheater and preheater at 200% boiler rating will be 90%.

8. It is easier to burn coal which is sensitive to smoke, entirely without smoke.

9. Elimination by introduction of heated air in refuse of continual cooling and heating of fine particles of ash, resulting in easier handling of refuse of fuel bed.

10. Preheated air changes the character, proportions and efficiencies of the fuel burning portions of the modern stoker.

*Selection and Maintenance of Oil Circuit Breakers**

By M. J. WOHLGEMUTH† and E. K. READ‡

THE subject of switching equipment for use in steel mill service is one, which up until recently has not received the consideration of the steel mill electrical engineers that it should. It is only within recent times, due to the rapid development of the Steel Mill Industry that this subject has come to the fore and has demanded attention.

It is the intention of this paper to take an imaginary steel plant and show the growth from its early stage up until the present time; to indicate during the various changes the effect on the equipment installed. The paper will also attempt to show how it is possible to calculate what the requirements of the necessary switching equipment will be to handle the service that is demanded, and also the care necessary to keep this equipment in good operating condition. This imaginary plant under discussion represents average growth. In this plant are located blast furnaces, open hearths, blooming mill drives, structural mill drives and various other

*To be presented at Twentieth Annual Convention, September 14 to 19, 1925.

†Switchboard Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

‡Circuit Breaker Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

mills and auxiliaries which are part of a large steel plant.

When originally built this plant, of course, like the rest of the older steel plants, had all main rolls steam driven. The use of electric power was therefore confined to lighting and small auxiliary service. For this reason the generating equipment consisted of a few gas engines. There were also installed a few motor generator sets for supplying D.C. power for various auxiliary drives and machine tools, power for mill lighting was obtained from transformer banks distributed through the plant. The installations of switching equipment corresponding to this period are very interesting in that they show the lack of attention given to what is now considered proper safeguarding of the equipment and the operators and the tendency to put equipment in a corner or in some crowded place which was entirely inadequate for the installation.

Figure 1 shows the switchboard and structure in the Power Plant of a Steel Company such as that

FIG. 1—Old Power House

under discussion and is probably typical of some of the older installations. It can be seen that a great deal of apparatus has been put into a restricted space giving rather crowded conditions and rendering it inconvenient for inspection of apparatus. One rather good feature is the fact that a brick wall is between the breakers and the operator thus giving some protection in case of trouble.

Figure 2 gives a good picture of how not to put in equipment, especially that of high voltage of the order of 6600 volts. This figure shows the apparatus for controlling one of the mill motors and speaks for itself.

Figure 3, which is one of the D.C. power distribution substations is a fairly good example of open bus work with conditions not so crowded. Figure 4 is another mill substation and is a pipe structure installation which gives adequate space for inspection. This substation is representative of those installed a few years ago.

This steel plant expanded in a normal manner and in line with this expansion it was decided to electrify one or two of the more important main roll drives. This made it necessary to put in a power house which contained two turbo generators. Blast furnace gas was burned under the boilers for generating steam. However, the demand for steel products at this time increased so rapidly that it became necessary for the steel plant to increase their productive power and also to cut the cost of production. In spite of the increased capacity and in-

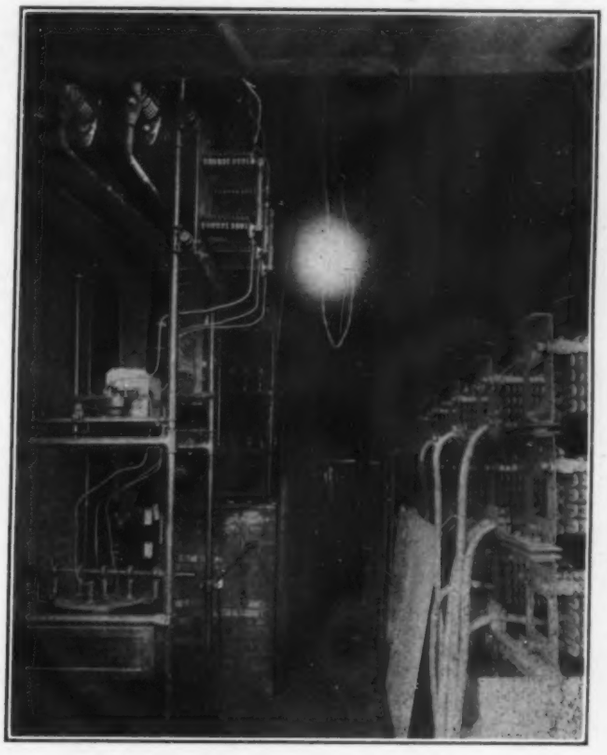


FIG. 2—Old Substation

crease in productiveness, due to the changes enumerated, the developments were much more rapid than had been anticipated and the steel plant found itself at a point where further increase in production could only be obtained by changing the equipment. Accordingly it was decided to electrify several more of the main roll drives. The first point that naturally arose was where the power was to be obtained. The question here was whether to put in additional generating equipment or to purchase power.

FIG. 3—Old Mill Substation

As the generating station, which had been installed in the plant was using all the excess gas available, the addition of further turbines and the corresponding increase in the boiler capacity would require more fuel. Accordingly it was decided to use purchased power by putting in a transformer substation and buying power from one of the Central Station Companies. As this plant was located near

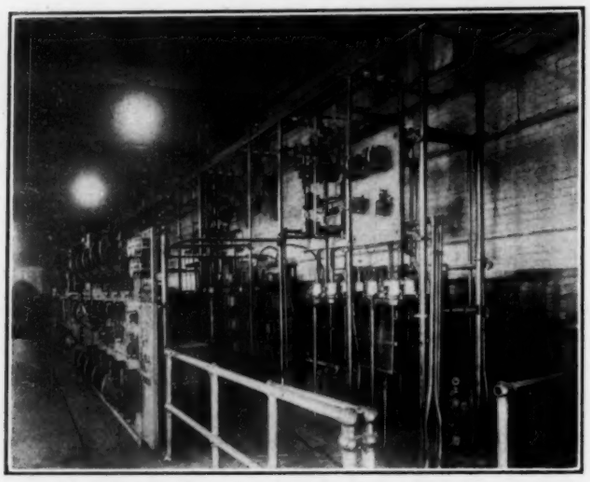


FIG. 4—Mill Substation (Recent)

a Power Company generating at the same frequency as that used by the Steel Plant, the only equipment necessary was a transformer substation. If the Central Station had not been able to furnish 25 cycle power to the steel plant, it would have been necessary to put in some sort of frequency converting equipment.

The use of purchased power and the installation of more synchronous apparatus in the mills, incident to putting in a large number of motor generator sets for auxiliary power, made it necessary to go over the distribution system in the plant and check up to see whether the apparatus as installed was capable of performing the functions demanded of it. Each individual part had to be checked as regards its appli-

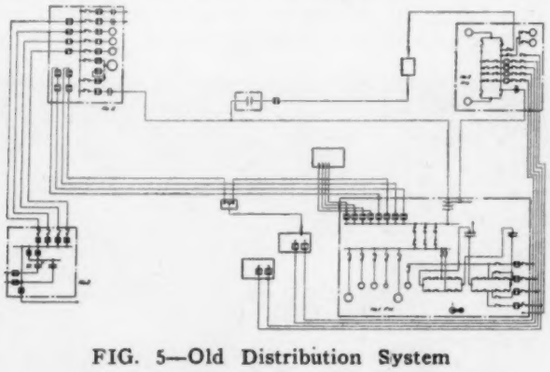


FIG. 5—Old Distribution System

cation and replaced if not adequate. In a large number of plants this was not done, with the result that when trouble occurred the apparatus installed was not large enough to successfully handle the situation and as a result serious delays were experienced.

The distribution system (Fig. 5) installed in the plant, was one which had expanded along with the normal growth of the plant, but apparently had not been given any engineering consideration during the expansion period. That is, the feeders were run in any manner convenient without reference to where they were tied in and as to the duty that the various circuits and switching devices were to handle. The investigation into the distribution system resulted in a new system being developed, consisting of a net work arranged in such a manner that trouble on any one or even two lines between various substations would not cause a complete shut down in those substations or any other substation in the loop. This was accomplished by looping the lines in and out of the various substations and making a ring system with a steam driven station at one end of the net work and the purchased power substation at the other part of the net work. This is shown in Figure 6.

On account of the importance of the proper selection of equipment for the service required it will no doubt be interesting to follow the methods by which the proper size and type of equipment is determined. From the system diagram shown in Figure 6, having the size and length of the various lines and the capacity of the various machines, it is possible to calculate the short circuit current which would occur at any point in the system by means of a calculating table. If access cannot be conveniently had to a calculating table it is possible to obtain ap-

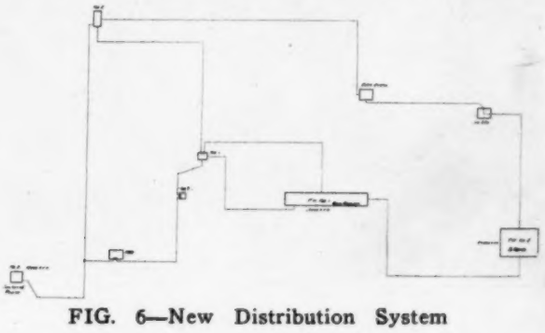


FIG. 6—New Distribution System

proximately the same results by means of resistance and reactance methods and thus to determine the size of equipment necessary. We shall show the method for calculating this current at one of the main mill substations.

The calculations shown are for the short circuit current of a mill substation which contains the electrical equipment for a large blooming mill. This mill can be fed from three sources of power, a steam turbine station, the old gas engine station and a transformer substation where purchased power is stepped down to 6600 volts, 3 phase, 25 cycle for the plant system. The mill substation is tied into the plant system by means of four lines, looping two in and two out, thus insuring continuous service even if line trouble exists between any two substations.

Transformer substation No. 3, with a capacity of 18,000 kv-a. has a reactance of 7 per cent; power house No. 1, with a total of 15,000 kv-a. has a reactance of 20 per cent, and power house No. 2, 25,000 kv-a. at 10 per cent reactance. All lines in the net work are single conductor, bare cable, except two runs from power house No. 1 which are lead covered, three conductor. The line reactances are first obtained as follows, the values for resistances and reactance being obtained from any hand book:

Line from No. 3 substation to No. 5 Substation four 500000 Circular Mil. each 3700 ft.

X = Reactance per mile = 0.226 ohms per mile.

R = Resistance per mile = 0.117 ohms per mile.

Z = Impedance per mile $\sqrt{X^2 + R^2}$ = 0.254 ohms.

Line impedance = $\frac{3700}{5280}$ X 0.254 = 0.177 ohms.

Impedance of four lines in parallel = ¼ x 0.177 = 0.044 ohms.

The capacity fed over these lines is 18,000 kv-a. at 6600 volts or 1575 amperes.

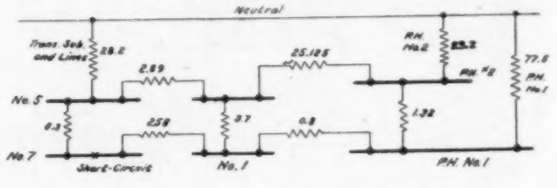
The impedance drop will therefore be 0.44 x 1575 69.4 volts.

The per cent reactance for the lines based on the capacity of the transformer bank is the ratio of the reactance drop to the normal voltage. It will be noted that impedance is used for line calculations instead of reactance. As the machine and transformer values are based on reactance only, this will introduce a slight error in the calculations. In a 25 cycle system the reactance is not great compared to the resistance and therefore, the latter must be taken into account. In a 60 cycle system, the reactance is much greater than the resistance and the latter can generally be ignored.

From the previous data:

Per cent line reactance = $\frac{69.4 \times 100}{\frac{6600}{\sqrt{3}}}$ = 1.8 per cent.

The total reactance of transformer and lines then is 7 + 1. 8 = 8.8 per cent based on 18,000 kv-a. In



Reactance Diagram for Improved Net-Work

FIG. 7.

like manner the per cent reactance of the other lines can be obtained. In each case the values are based on the capacity that can be fed over the lines. The total power available is 58,000 kv-a. at 6600 volts, so that the final value will be based on this capacity. The per cent reactances of the whole system, lines and generating stations are reduced to a common base, in this case 58,000 kv-a.; for example the reactance of 8.8 per cent based on 18,000 kv-a. becomes $\frac{58,000 \times 8.8}{18,000}$ = 28.2 per cent based on 58,000 kv-a

In cases where two parallel circuits feed from one station to another the per cent reactances are treated like resistances and are combined according to Ohm's Law.

Where a number of different loops feed a particular substation bus, probably the simplest method of solving for short circuit current is to use the reactance diagram. The reactance diagram will be as shown in Figure 7. It will be readily seen that the reactance of power house No. 2 and the lines between power house No. 1 and No. 2 from a delta which can be changed to a star by means of a simple formula as shown in Figure 8A:

$B_1 + B_2 + B_3 = 102.02$

$A_1 = \frac{B_2 \quad B_3}{B_1 + B_2 + B_3} = \frac{77.5 \times 23.2}{102.02} = 17.6$

$A_2 = \frac{B_1 \quad B_3}{B_1 + B_2 + B_3} = \frac{77.5 \times 1.32}{102.02} = 1.0$

$A_3 = \frac{B_2 \quad B_3}{B_1 + B_2 + B_3} = \frac{1.32 \times 23.2}{102.02} = 0.31$

The right hand portion of the diagram then assumes the form shown in Figure 8B. We now have

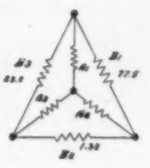


Fig 8A

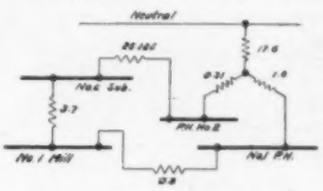


Fig 8B

Steps in Solution

several reactances in series which can be combined to further simplify the diagram,

1.0 + 0.8 = 1.8 to No. 1 Mill

25.125 + 0.31 = 25.4 to No. 2 Substation.

Another delta is then formed by reactance 25.4, 1.8, and 3.7. By using the same method as outlined above a star is obtained, making the diagram appear as in Figure 9A. The reactances can then be further combined as follows:

17.6 + 14.75 = 32.35

3 04 + 2.89 = 5.93

0.215 + 2.58 = 2.8

Another delta is formed by reactances 5.93, 2.8, and 8.3 which can be converted into a star, making the diagram appear as in Figure 9B. Combining reactances in series we have,

32.35 + 0.975 = 33.325

28.2 + 2.89 = 31.09

Reactance 31.09 represents that of the transformer bank which is connected to the Central Station lines. As the Power Company's generating capacity is

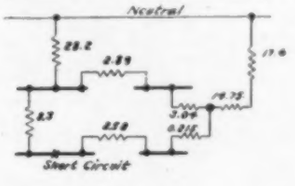


Fig. 9A

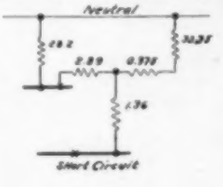


Fig. 9B

Steps in Solution

great compared to the transformer bank at the Steel Plant the current delivered to the short circuit through the bank will be sustained.

Figure 10 shows a set of decrement curves which are used in calculating the resultant current after a definite elapsed time, and Figure 11 shows the same curves in a different form.

The reactance of the transformer bank and lines is 8.8 per cent on the basis of 18,000 kv-a. The short circuit current delivered to point A (Figure 9B) will

be approximately 18,000 amperes. The reactance of generating stations and lines to Point A is 33,325 on 58,000 kv-a. or 23½ per cent based on 40,000 kv-a. generator capacity. The current delivered by these units will not be sustained as their size is not great enough to hold up the voltage. Referring to Figure 10, the instantaneous rush of current for a reactance of 23.5 per cent is 8 times normal, and the ¼ second value is 4 times normal. The ¼ second value of value for which the breakers should be selected is approximately 14,000 amperes. The total current delivered to point A is therefore 32,000 amperes. Since the line from "A" to the Substation is very short and the reactance practically negligible we can use the value obtained above (32,000 amperes) as the current that the breaker selected should interrupt.

The corresponding value for any other point on the system can be calculated in a similar manner. It should be noted that in calculating this current all

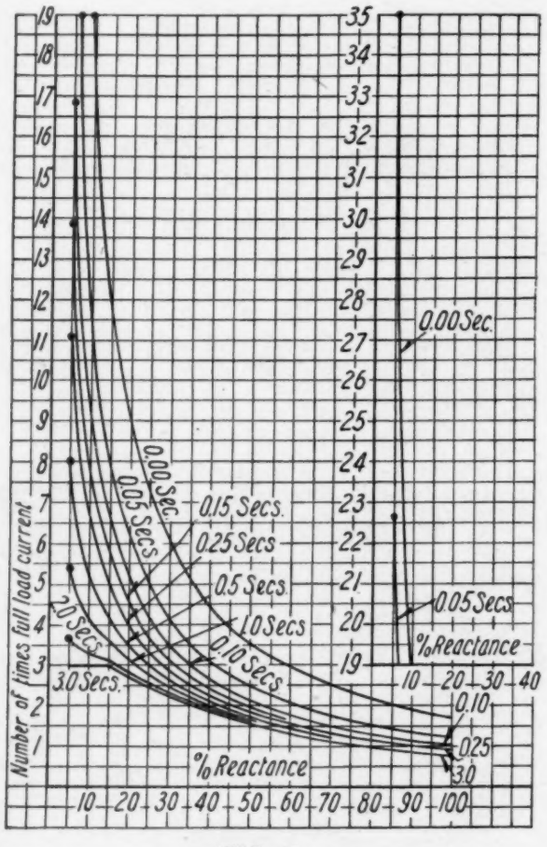


FIG. 10.

machines are considered to be running and that all lines are tied in. Obviously this procedure is not quite correct, as at least one machine in a generating station would probably be in reserve and not all the lines will be in service.

In making these calculations we have used reactances of machines and transformers, and impedances of lines, which introduces an error as stated before. If reactance of lines only had been considered a value of possibly 15 per cent below that obtained would have resulted. Our figure for short circuit currents is therefore on the safe side and offsets a number of assumptions we made such as assuming that the power factors of the lines, generators, load and transformers are the same. It should be understood also that the value of short circuit current obtained is approximate only and that if highly accurate methods were used and all possible factors taken account of, that a different result would have been obtained. It would probably be found that the figure we have would be within 10 per cent of the accurately determined one, so that the error is not so great.

The value obtained above is the R.M.S. symmetrical current. Experience with numerous short circuit tests has shown that an unsymmetrical value of nearly double its symmetrical value may be possible. It is therefore evident that great care must be used in designing the circuit breakers and switching equipment to see that the apparatus is able to withstand the mechanical forces set up by this current. This current returns to normal within a very few cycles and the maximum dies down generally as shown in previous figures.

It is common practice to relay the various circuit breakers so that the fault can be eliminated from the system by the opening of the fewest and closest circuit breakers. This selective relay action sometimes requires that the circuit breaker carry the sustained short circuit current for periods of from a fraction of a second up to two or three seconds.

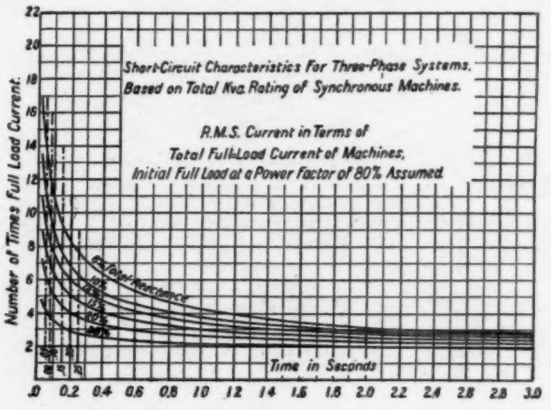

Short-Circuit Characteristics For Three-Phase Systems.
Based on Total Kva. Rating of Synchronous Machines.
R.M.S. Current in Terms of
Total Full-Load Current of Machines,
Initial Full Load at a Power Factor of 80% Assumed.
Number of Times Full Load Current.
Time in Seconds

FIG. 11.

It is therefore important that the circuit breaker be able to carry the sustained short circuit current for a definite period of time. The standard time on which circuit breakers are rated is 5 seconds. To carry this sustained current each circuit breaker must be mechanically strong enough to withstand the mechanical forces of the magnetic field set up by the current. It is especially essential that the contacts be able to carry this current without opening. This force makes it necessary on heavy currents to use a parallel path or reversed type of contact brush. On the lower values of current it is only necessary for the contact to be sufficiently stiff to withstand the current for which it is rated.

After the relays have functioned to trip the circuit breaker, it is necessary that the circuit breaker be capable of interrupting the current that may be in the circuit. Interrupting capacity ratings of circuit breakers are based on the cycle as given in the standardization rules of the American Institute of Electrical Engineers.

The modern oil circuit breakers to a very large degree are service tested devices, the apparatus or

the equivalent of the apparatus has been in service for a long period of time in a number of plants. Of late, power companies have been co-operating with the manufacturers very closely in making field tests on circuit breakers and switching equipment within the limits of their system capacity. It is through this co-operation that the knowledge of the circuit breaker art is being increased. As the amount of this knowledge grows and as the ability of each individual piece is verified it immediately becomes that much less of a problem to properly design an adequate circuit breaker.

Moderate circuit breakers are designed for great ruggedness. They are designed to withstand, with a good margin of safety, continuous use at or near their rating. The circuit breaker may never be called to open the maximum short circuit possible on a circuit. It must, however, always be ready to do so if called upon.

In the opening of a short circuit, the circuit breaker must have sufficient strength to withstand the pressure generated within the tanks by the arcing which vaporizes the oil. Anything which tends to cut down the time of the arcing will increase the ability of the circuit breaker by the same amount.

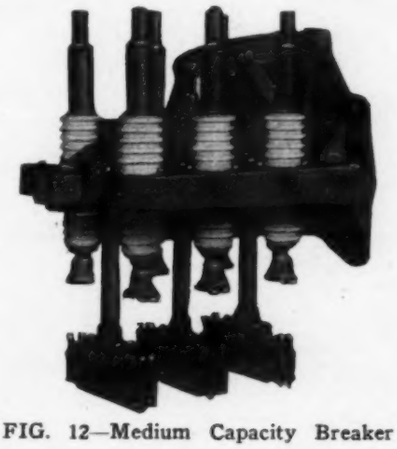


FIG. 12—Medium Capacity Breaker

An adequate head of oil must be provided over the point of arcing to insure that the arc gasses are cooled sufficiently by their passage through the oil to prevent their ignition after they arise above the surface. The main contacts should be adequately protected by auxiliary arcing contacts to prevent burning of the main contacts. The contacts which take the arcing should be renewable, so that a minimum amount of time will be consumed in renewals and maintenance. The entire structure should have sufficient strength so that oil and gas will not be expelled in objectionable quantities during the operation. The design should be such that the oil and gas which is expelled will not be ignited outside of the circuit breaker. All of the operating details should be designed so that the failure of some small piece will not cause a circuit breaker failure. Dependable operating mechanism must be provided; they should be simple in design and so made as to give a maximum of service with a minimum amount of attention.

The design of the insulating details of the circuit breaker is fairly easy, in that it is merely a matter of providing sufficient distances to ground through the air and over the surface of the insulation. An insulation test of the circuit breaker as a whole or of any of the details is very easily applied during the building of the circuit breaker or after it is installed. The insulating material should be of sufficient strength to withstand the shocks of cir-

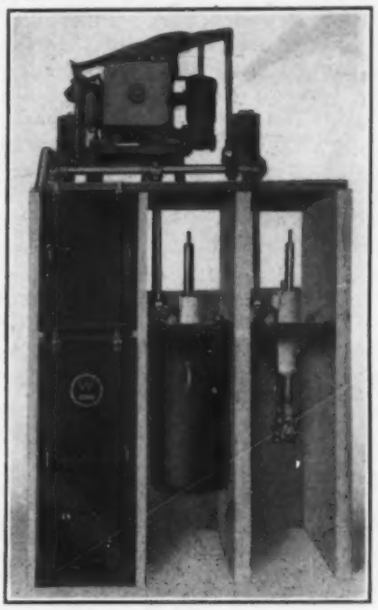


FIG. 13—Large Capacity Breaker

cuit breaker operation, both when closing and opening and when carrying the initial rush of current. It should also be able to withstand a reasonable amount of handling during the shipping and installation period.

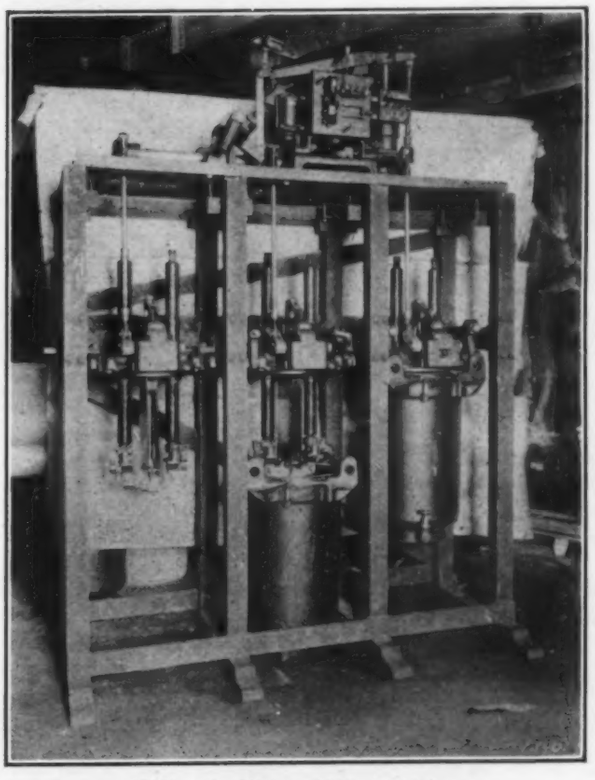


FIG. 14—Heavy Duty Breaker

The design problem of providing sufficient conducting material, so that the circuit breaker will carry its rated current without overheating, is not very difficult. Present day knowledge has rather definitely settled the amount of copper and conducting material that is necessary to carry a given current at a given frequency. Temperature tests on any piece of apparatus are easily made before it is installed by using a low voltage high current source. Temperature tests are not easy to obtain after the apparatus is once installed. The temperature of the contacts of the circuit breaker in service can be very closely approximated by reading the temperature of the oil container. The difference between this temperature and the temperature of the contacts will vary with different types of apparatus but will give a good indication.

Figure 12 shows a circuit breaker for use on steel mill service for light rupturing capacity duty. This circuit breaker, as can be seen from the figure, is very rugged and substantial. The type of contact shown is of the brush type and is protected by butt type of arcing contacts. Figures 13 and 15 show a heavier type of circuit breaker, quite commonly used for steel mill service. The figures show this circuit breaker to be of the individual pole, common operating mechanism type. The operating mechanism is carried on a structural steel base on the top of the cell structure. The cell walls form individual barriers between the pole units, thus confining any disturbance that may start to that particular phase. These pictures show the parallel path type of brush designed to insure that the contacts will not open under heavy short circuit currents. Here again the simplicity and the ruggedness of the apparatus is evident. Figure 14 shows a heavier design of circuit breaker. The picture shows that the apparatus is of the same general type, with the parts strengthened as necessary for the heavier duty.

Steel mill service is about as severe a service as is required of switching equipment. The air is filled with dust of a metallic nature and gases which have

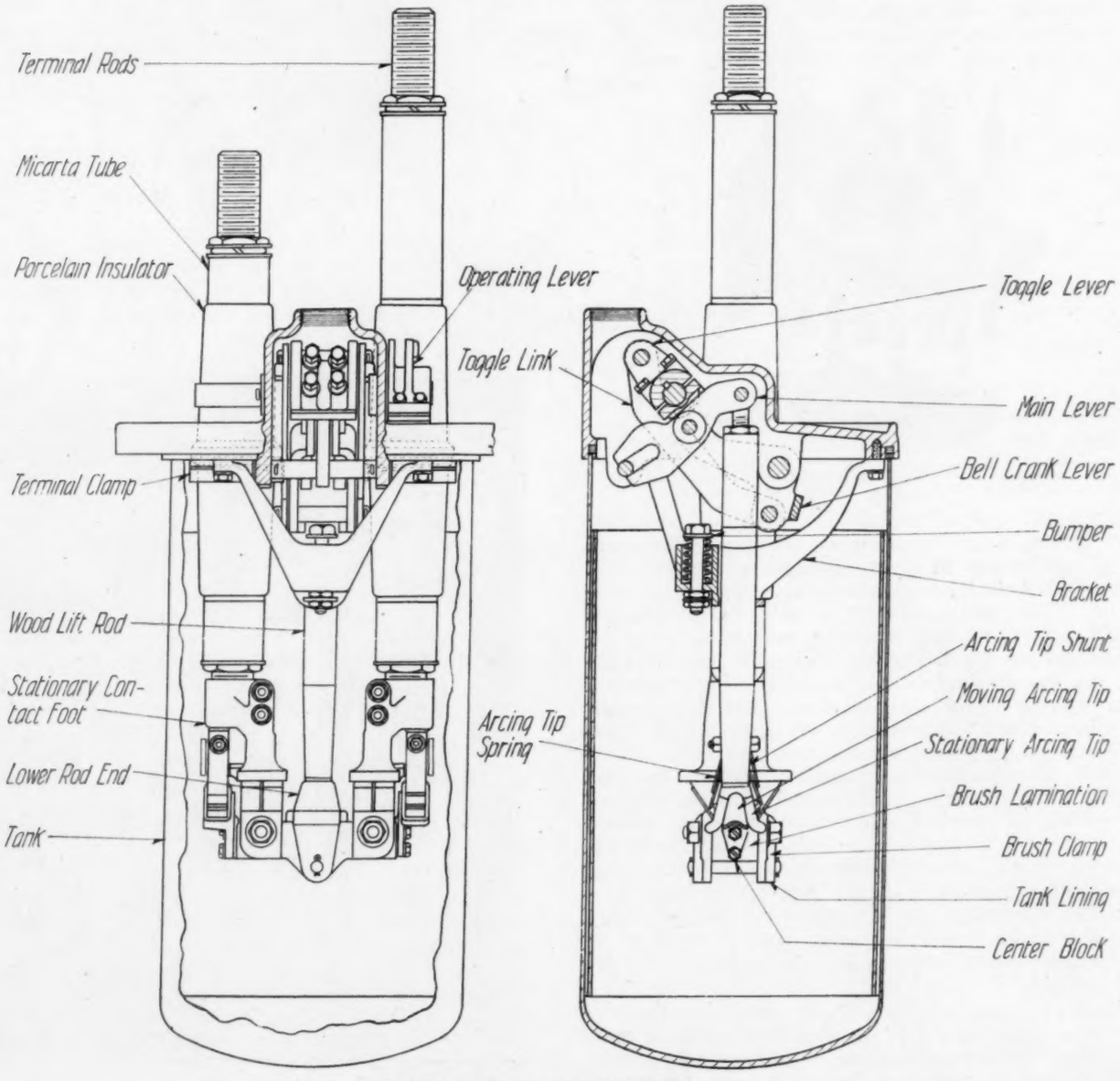


FIG. 15—Large Capacity Breaker

a strong deteriorating effect upon electrical apparatus. Apparatus intended for application in steel mills should, therefore, be more rugged and have a wider margin of safety than that for ordinary service. Extra ruggedness is usually obtained by using the best apparatus available upon the market. Extra margin can be obtained by specifying apparatus of the next class to that which would just barely meet the service. On account of the air conditions in steel mills, it is now fairly well standardized practice to install apparatus with a voltage rating at least double that of the circuit to which it is applied.

It is usual to supply, especially on important circuits, apparatus of a heavier current carrying capacity than that which is just large enough. All of these precautions tend to keep down outages, to keep down maintenance, and keep up the "availability of service."

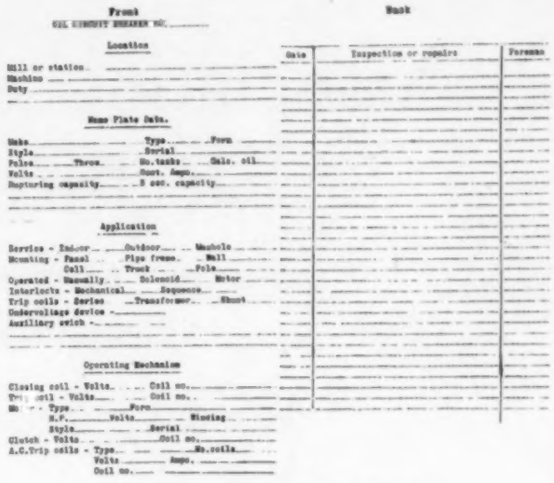
Switching equipment for steel mill use should be kept in the very best possible condition. No opportunity for inspection should be permitted to pass unused. A hurried inspection, if that is all that is possible in the time available, may detect a condition that is easily remedied at the moment. This minor difficulty, if allowed to stand, may at some future time result in an outage of the circuit and may shut down the entire mill, because of the correlation of the apparatus in the mill.

Maintenance is not to be looked upon at all as a matter of "coddling" of weak apparatus. The very best apparatus will perform better, stay on the line longer, and give less trouble if properly maintained. Sometimes apparatus known to be on the "ragged edge" can be kept in place and give good service until such time as it is possible to replace or repair it by giving it just a little better than ordinary supervision. In any power distribution system there is always one or more weak points. Attention paid to these will be more than repaid in the smooth, continuous performance of the entire equipment.

A certain amount of inspection of the apparatus may be made while the apparatus is in service. It is possible to observe the operation of the circuit breakers and obtain a fair idea of their condition by watching their operation. The external mechanism can be looked over, while keeping at a safe distance, for conditions which might later cause an outage if not corrected. The general temperature of the apparatus can be observed from a safe distance. Any condition which may not be corrected in a few moments or while the apparatus is alive should be noted and the correction made at the first opportunity. A record should be kept of all apparatus, giving the date and degree of inspection. A schedule should be made out, giving desirable periods for casual inspection and for thorough inspection. Opportunity should be watched for, so as to make the inspection as close as possible to schedule. In case it is impossible to get a piece of apparatus out for inspection for a period of time that greatly exceeds the specified period, then this piece of apparatus should be watched more carefully than usual until it receives the desired inspection. Figure 16 shows the record kept by one company in a very convenient form. The front of this card gives data regarding the manufacture and rating of the apparatus. The back of the card is used to indicate the date and degree of inspection and can also be used to indicate any repairs that may have been made on the apparatus, as well as the date of the repairs. In this way the engineer is able to tell at a glance the condition of his apparatus.

An alert operator can make himself very valuable in the preventing of outages by watching his apparatus with the idea of continuity of service in mind.

It is now becoming standard practice with most operating companies to make a complete check of the condition of the circuit breaker after a given number of operations. One operating company


Front

OIL CIRCUIT BREAKER NO.

Location

Mill or station

Machine

Duty

Name Plate Data.

Make Type Form

Style Serial

Poles Throw No. tanks Galo. oil

Volts Short. Amps.

Rupturing capacity K sec. capacity

Application

Service - Indoor Outdoor Manhole

Mounting - Panel Pipe frame Wall

Cell Truck Pole

Operated - Manually Solenoid Motor

Interlocks - Mechanical Sequence

Trip coils - Series Transformer Shunt

Undervoltage device

Auxiliary switch

Operating Mechanism

Closing coil - Volts Coil no.

Trip coil - Volts Coil no.

Mo Type Form

H.P. Volts Winding

Style Serial

Clutch - Volts Coil no.

A.C.Trip coils - Type No.coils

Volts Amps.

Coil no.

Back

Date	Inspection or repairs	Foreman

FIG. 16—Inspection Card

drops the tanks on the circuit breaker, inspects the contacts, checks the condition of the oil, and generally looks over the circuit breaker after every operation of the circuit breaker under short circuit conditions. The service record of the apparatus of this customer is unusually good. Another operator gives his circuit breakers similar attention after three automatic operations. This same operator checks the condition of his apparatus completely every six months, whatever its operating record. This operator also gets very good service from his apparatus.

Obviously the degree of maintenance is determined by the severity of the service. It is recommended that the apparatus be looked over after functioning on a short circuit. The circuit breaker should be checked after five to ten automatic operations, paying particular attention to the quality of the oil, to see that the arcing within the apparatus has not reduced the insulating quality of the oil to an undesirable degree. The circuit breaker should be looked over after approximately 50 to 100 operations to see that no parts have loosened or become displaced and the quality of the oil tested as a matter of routine to insure that everything is in good condition. The check on this service should show nothing out of order and will probably act mainly to place at rest any uncertainty regarding the condition of the apparatus.

It should be borne in mind that where we refer to apparatus being inspected after functioning on a short circuit, we mean that after the breaker has performed its duty cycle in accordance with the A. I. E. E. and N. E. L. A. rulings, i. e., 2-0C0 at two-minute intervals. Where the breaker operates on overload due to the action of protective relays, the inspection should not be so frequent, an inspection after five or ten operations being considered adequate.

SAFETY DIVISION

First Annual Meeting

Auspices

Association of Iron and Steel Electrical Engineers

Chrystal Ball Room,
Benjamin Franklin Hotel

Monday, September 14th, 1925.

—PROGRAM—

12:30—Luncheon

CHRYSTAL BALL ROOM

1:30—INTRODUCTION—A. C. CUMMINS, President, A. I. & S. E. E.

REMARKS—L. H. BURNETT, General Chairman, Safety Division, A. I. & S. E. E.

REMARKS—C. L. BAKER, Vice Chairman.

REMARKS—HENRY A. RENNINGER, Vice President, National Safety Council.

Paper

How the Electrical Engineer and the Safety Engineer can be Mutually Helpful—

By John A. Oartel, Chief of Safety Bureau,
Carnegie Steel Company, Pittsburgh, Pa.

Executives, Safety Directors, Electrical Engineers and Superintendents, Combustion, and Mechanical Engineers of the Iron and Steel Industry are urged to attend this meeting.

VISITORS ARE WELCOME.